URANIUM IN SOUTH AFRICA

1946 - 1956

VOLUME 1

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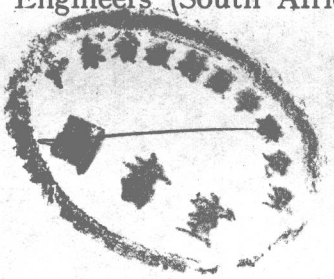
The South African Institute of Mining & Metallurgy

The South African Institution of Mechanical Engineers

The Institution of Chemical Engineers (South African Branch)



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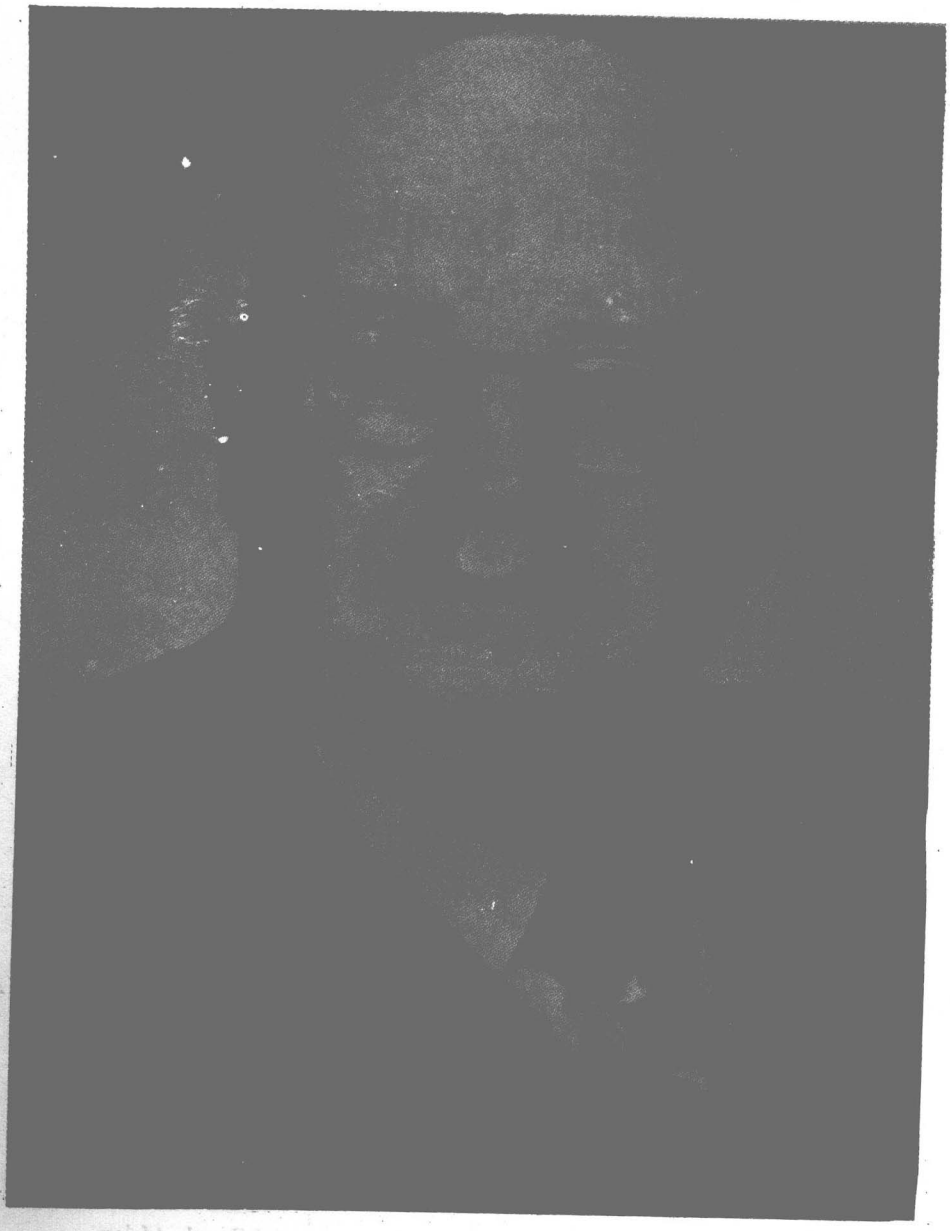


DR. THE HON. A. J. R. VAN RHIJN

Foreword

IT is both an honour and a pleasure to provide a foreword to a volume, the purpose of which is to record the efforts of many South Africans who have contributed to the establishment of the uranium industry on the Rand.

That an industry at present treating approximately twenty million tons per annum of gold ore residues arising from twenty-four gold mines has been initiated and brought to full production within a period of approximately ten years must, judged by any standards, be regarded as a phenomenal achievement and one that has already proved of immense significance to the economic structure of the Union. In addition, the fact that five of our technical societies are jointly responsible for this publication indicates both the co-operative effort that was essential and its practical realisation. This collection of papers does not, however, reveal the complete picture since the mining industry, whilst accepting the responsibility placed on it by the Government for the design, erection and operation of the plants, in turn made demands on other branches of industry. Considerable additional electrical power has had to be made available, whilst the plants embody materials and equipment new to South Africa which have required specialised techniques and personnel in their utilisation.

These demands arising, as they did, so soon after the termination of the Second World War, strained our limited resources to excess. Certain essentials, notably equipment for power generation, structural and special steels, were in great part made available by the United States and Great Britain on a priority basis. Without this assistance and the financial help provided it would have been impossible to complete the programme according to schedule.

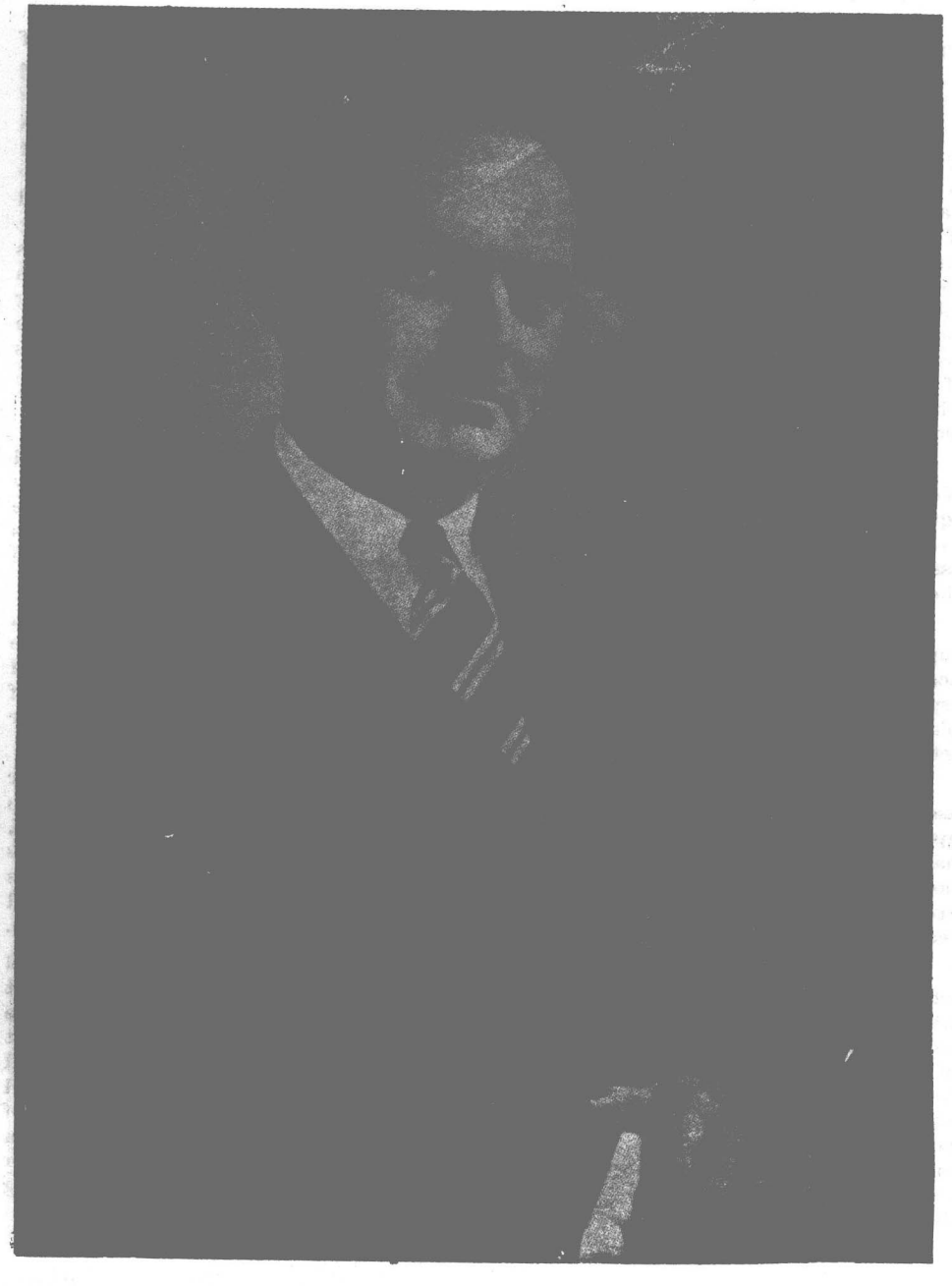
The technical personnel involved were, however, with certain notable exceptions, supplied almost entirely from our own resources. Basically it has been the accumulated knowledge and experience of the Transvaal gold mining industry, and especially the associated technical personnel, that have enabled this large number of plants to come into full operation with practically none of the teething troubles or other setbacks to which such undertakings are so often subject.

This new industry may well be regarded as only the forerunner of further associated developments. There can no longer be any doubt that the world is approaching the era of nuclear power generation, and Mr. R. B. Hagart, in his paper, has indicated that the Union of South Africa should for many years be able to retain its position as one of the major world suppliers of nuclear fuel. It therefore appears appropriate that the Union should, with due regard being given to its financial and technical resources, be prepared to make a substantial effort to foster these developments.

The Union is richly endowed with adequate supplies and ample reserves of solid fuel which are available at exceptionally low cost. It must, however, be anticipated that within the foreseeable future nuclear power will, even in South Africa, become competitive in areas remote from the coal deposits or difficult of access. The development of such areas within the Union and South West Africa has undoubtedly been hampered by their geographical situation. Thus the Union, notwithstanding its cheap and abundant coal supplies, still has an important domestic interest in the generation of power from nuclear sources. It may, therefore, be anticipated that the Union, as a major producer and potential consumer of nuclear fuel, will furnish opportunities for its trained technical personnel to make further contributions in this rapidly advancing field of scientific endeavour.

A. J. R. VAN RHIJN,
Minister of Mines and Chairman,
Atomic Energy Board.

CAPE TOWN,
28th May, 1957.



C. B. ANDERSON

Introduction

FOR some time the need has been apparent for an authoritative and comprehensive volume on the techniques and processes of the South African uranium industry. The publication in this book of the papers presented to the recent symposium on uranium production provides a standard work of reference on the subject. The emergence of the present volume would be significant enough at this stage, if it served no other purpose than that of a store of knowledge and experience of the processes used in the uranium industry. The volume is, however, much more than that. It is a record of achievement of which South Africa has every right to be proud.

Details of the establishment and development of the South African uranium industry were perforce kept secret for so long that the initiative, skill and co-ordinated effort behind the creation of this new industry did not receive the wide acclaim they so richly merited.

Uranium in South Africa—1946-1956, in addition to being a reference work, is a tribute to the scientists, geologists, metallurgists, engineers, technicians and others whose ability and ingenuity were so strikingly demonstrated in the establishment of this industry.

We in the mining industry have for a long time recognized that South Africa is well endowed with talent in the scientific and technical fields. The confident adoption of new techniques in the skilful and expeditious solution of many novel problems involved in establishing the uranium industry was most gratifying. No less pleasing was the realization that processes in the gold mining industry had been developed to so high a state of efficiency that they were readily adaptable to the new industry. These facts provide further proof of the quality of our scientists and technical men. It is a quality that augurs well for the future development of our country.

Uranium in South Africa—1946-1956 was written by experts in the various fields covered—most of them were closely associated with the industry during the formative years. To the valuable contribution they had already made to the establishment of the industry they have now added their share in the compilation of this important record and work of reference. It was not to be expected that their approach to their subject would be a romantic one. For the imaginative reader, however, these pages must reflect something of the urgency and complexity of the initial task, of the resource and vigour with which obstacles were surmounted, of the ingenuity with which techniques and processes were evolved or adopted, and of the collective effort without which the establishment and extraordinarily rapid development of the new industry would have been impossible.

I am proud of the part played by the mining industry in this remarkable co-operative achievement and of what was accomplished through the readiness with which the industry pooled its resources and experience to make uranium production in South Africa a reality.

I am proud, too, to be able, on behalf of the Chamber of Mines, to offer this brief introduction to a work that is a lasting tribute to the scientists and technical experts of South Africa.

C. B. ANDERSON,

President (1956-1957)

Transvaal and Orange Free State Chamber of Mines

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VOLUME II

An Historical Review of the Events and Developments Culminating in the Construction of Plants for the Recovery of Uranium from Gold Ore Residues.

By Professor L. Taverner

The primary purpose of this historical summary is to record the events which led to a very exhaustive programme of chemical metallurgical investigation and resulted in the establishment of a uranium extraction industry on the Rand in a period of less than 10 years.

The work was undertaken jointly and with complete co-operation by the Massachusetts Institute of Technology Laboratory in the United States of America, the Chemical Research Laboratory, Great Britain, the Bureau of Mines Laboratory, Ottawa, and the Government Metallurgical Laboratory in the Union. In addition the Union Geological Survey, with the active co-operation of the gold mining industry, was responsible for the physical determination of the uranium content of some 400,000 underground samples of ore collected from various reefs on selected mines and in addition the similar examination of a very large number of dump residue samples.

The first notification that the Rand gold ores contain radioactive substances dates from 1915 and is attributed to Dr. A. W. Rogers, Director of the Geological Survey of the Union of South Africa at that time. In 1923 Mr. F. Wartenweiler, then Assistant Consulting Metallurgist to the Central Mining Group of Companies, initiated an investigation into the mineral constituents of the corduroy concentrates. This Group had then decided to change over from plate amalgamation to corduroy concentration for the recovery of free gold, with the result that the amount of concentrate collected was in excess of amalgamation barrel capacity. The concentrate obtained from the corduroys was being re-treated on tables, and it was the detailed examination of these table concentrates which revealed the presence of relatively large amounts of osmiridium together with a radioactive mineral subsequently identified by Cooper as a variety of uraninite. The findings were published in a paper presented to the Chemical, Metallurgical and Mining Society of South Africa by him in October, 1923. It is a curious coincidence that it was the occurrence of another uranium mineral, namely, thucholite, a hydrocarbon mineral in a mine (Blyvooruitzicht) controlled by the same mining group, which first attracted attention in the more recent investigations now to be described in a series of papers for which this summary serves as an introduction. Cooper's identification of a heavy black mineral of specific gravity between 9—10 was not, so far as it has been possible to ascertain, accompanied by any attempt to determine the amount of uranium present in the original ore. This is understandable since the occurrence of uranium in such minute amounts could not, at that time, have been of any economic significance. Nevertheless the uranium-bearing product recovered was found to contain 49·1 per cent. U_3O_8 and 1·6 per cent. ThO_2. Prior to the development of the atomic weapon, world demand for uranium was small, the limited amount required industrially being utilized almost exclusively by the glass, ceramic, and pigment industries. This demand was more than satisfied

from several rich mines of limited extent, notably those located in Central Europe (Joachimstal), the Belgian Congo (Shinkolobwe) and the Great Bear Lake deposits in North Canada. Until the commencement of the Second World War these deposits were operated primarily for the extraction of radium and subsequent recovery of the precious metals values in the residues. The final uranium residues from these and other operations were accumulating since the amounts available were in excess of world requirements. Much the same position existed at the vanadium plants situate on the Colorado Plateau in the United States where uranium was recovered as a by-product. It was from certain of these sources, all of them very many times richer in uranium than the gold ore residues about to be considered, that the uranium supplies required for the initial atomic weapons were provided.

With the advent of atomic energy the whole position completely changed, with the result that early in World War II the Governments of the United States and Great Britain were sponsoring jointly world-wide prospecting programmes for the discovering of new sources of supply. Mr. Jesse Johnson, in a paper presented at the recent Geneva Conference, mentions an expenditure of some $46,000,000 for exploration and development of exploration methods. As a part of this programme an intensive search of technical literature was undertaken in the United States under the direction of Joseph Sinclair, during which R. A. Cooper's paper, previously mentioned, came under review. As a result Weston Bourret was, in May 1944, commissioned to visit South Africa for the purpose of studying and reporting on this occurrence. Bourret, in company with an Assistant Geologist, Frank West, spent four months in the Union investigating and sampling operating properties on the Rand. Over 100 mill products and ore specimens are said to have been collected for preliminary radiometric assay and this examination was supplemented by chemical analyses and mineralogical studies in the United States, the latter carried out by Dr. D'Arcy George. In the spring of 1945 a preliminary report was completed and the findings were submitted to Professor G. W. Bain of Amherst College, then serving on an Advisory Committee appointed in connection with the Manhattan project to enquire into potential sources of uranium.

Professor Bain had previously made an extensive tour of the Rand goldfields during which he had collected hand-picked specimens of geological interest. These he then examined for radioactivity and confirmed the presence of radioactive minerals in what he must have regarded as appreciable and very significant amounts, bearing in mind the very large tonnage of ore treated on the Rand. It thus appears that the first chemical determinations of the uranium content in Rand gold ores were made on samples collected by Bourret and it is not known what figures were obtained. Later events suggest that the values were appreciably in excess of the values of run-of-mine ore treated in the reduction plants of the mines examined. In any case they were regarded as sufficiently important to justify an urgent approach being made to the South African Government regarding the possibilities of extraction and recovery of uranium from the very large tonnages treated. The immediate result was a Government-sponsored visit to the Union late in 1945 by Professor G. W. Bain and Dr. C. F. Davidson, then Chief Geologist of the Atomic Energy Division of the Geological Survey of Great Britain. During this visit arrangements were made, through Dr. L. T. Nel, of the South African Geological Survey, for underground examination of several mines, using a portable type of Geiger counter

supplied from the United States. It has always been assumed that this was the first occasion on which a Geiger counter was employed underground in South Africa, but some doubt now arises as to whether Bourret used a similar type of instrument for his earlier surveys. Mention must, however, be made that the South African Geological Survey were already making radiometric determinations on ores, using an instrument designed by the Bernard Price Institute, and calibrated by means of a synthetic standard based on chemical analyses provided by Chemical Services. This instrument had not, however, been used on Rand ores but on ores of much higher radioactivity from the Cape area. Small hand samples of ore were collected and taken back to the United States and Britain for further examination.

At the request of Professor Bain provision was also made for the collection by the Geological Survey and despatch via the Government Metallurgical Laboratory to the United States of a series of 200 lb. samples from each of the following mines—Blyvooruitzicht, Vogelstruisbult, Western Reefs, and East Daggafontein. The samples from each mine were split into three portions; one portion of each was sent to the United States, one portion retained at the G.M.L. for test work, and the third portion reserved for despatch to the United Kingdom if required. These samples were all obtained by selective mining, had very high values for both gold and uranium and did not in any way correspond to the ore that was mined for treatment in the reduction plants.

After a short interval a further request was received for 5-ton samples from the same four mines which, based on the information then available, were requested to contain a specified minimum uranium content. Again these samples had a uranium content greatly in excess of the value contained in the run-of-mine ore. They were only obtained with considerable difficulty by the Geological Survey and followed the same procedure as the previous samples in respect to sampling and despatch. At this stage the Laboratory again drew attention to the fact that the uranium contents of these samples were considerably in excess of the content of run-of-mine ore obtained over a full stoping width, and also that the lower grade ore would be the only material that could be mined on a large scale. Nevertheless, in view of the specific request, it was decided to despatch the samples whilst at the same time drawing the attention of the United States authorities to the position. These facts are of particular interest since they appear to indicate that the United States authorities up to that time might have been regarding the Rand deposits as of much higher grade than they actually were, or alternatively that selective mining would be practicable to provide rich material of the grade requested.

This leaves a doubt as to whether these deposits would initially have attracted the serious and urgent interest they did if the correct value of the ore as mined had been fully realised. The provision of this particular rich Blyvooruitzicht sample also focused attention on the fact, subsequently fully established, that underground determinations by radiometric methods could be misleading owing to contamination of stopes with uranium-rich dust from previous blasting operations. It is understood that the radiometric determinations made underground were appreciably higher than the duplicate determinations made on the same sample after it had been brought to the surface. The Geiger counters available at that period were relatively insensitive

instruments as compared with those now available, whilst it has subsequently been established that the standard samples used for their calibration were in some instances unreliable. The position may be judged from a statement made by Professor A. M. Gaudin in a paper he presented at the recent Geneva Conference where he mentions that the original 200 lb. sample from Blyvooruitzicht was presumed to contain 0·5 per cent. U_3O_8, although it was subsequently shown to contain less than a third of that amount.

Two of the 5-ton lots were despatched to the M.I.T. and two to the Bureau of Mines Laboratory in Ottawa. The position had by this time somewhat changed and doubts were being expressed by certain authorities both as regards the accuracy of the uranium assays and the ability to establish an economic process of recovery on such low grade material. At the request of the late Mr. Arthur D. Storke, who had been engaged by the British authorities to investigate the position, assay samples were prepared from each of the four 5-ton lots of ore shipped overseas for submission to a number of recognised laboratories conversant with uranium analysis. The chemical determination of uranium in ores in amounts little more than traces was a matter which at that time had been given very limited attention. The returns from the various laboratories differed by as much as 300 per cent. for the higher values and showed an even greater divergence for the lower values, with in one instance a nil return. The G.M.L. had in the meantime commenced a detailed mineralogical examination of the Blyvooruitzicht ore and had ascertained that at least a considerable portion of the uranium content was locked as minute particles of uraninite in a hydrocarbon mineral, thucholite. All assay samples at the Laboratory were therefore calcined at a low temperature to remove the hydrocarbon and expose the uranium minerals before bringing them into solution for analysis. These initial samples were assayed by Mr. D. Millin in the Metallurgy Department of the University and ultimately the results he provided proved to be the most accurate. Subsequent experience has shown that calcination is not essential using present assay methods, although it is desirable for samples containing appreciable quantities of the hydrocarbon uranium mineral, thucholite. The reasons for the analytical differences then encountered have never been completely explored or properly explained.

These analytical errors have been dealt with in some detail to indicate the difficulties that were being encountered in determining accurately the uranium content of very low grade ores at the outset of this investigation. In addition they emphasise the advances that have been made during the last 10 years but not without painstaking effort and very appreciable skill on the part of those immediately involved. Those who have simultaneously developed the physical methods are equally to be commended but it must not be overlooked that the ultimate accuracy of such methods rests with the analytical chemist who provides the standards. It cannot be too often repeated that a very large part of the total effort which has led to the development of a satisfactory extraction process has been related to the provision of methods and facilities for the rapid and accurate determination of uranium in very small amounts on a routine basis. Initially progress was slow and the methods in use were laborious, requiring careful control and painstaking effort if accurate results were to be obtained. This position was periodically subject to definite improvements and changes in method until to-day uranium assays are accurately performed with

comparative speed on a routine basis. In this connection the analytical staffs of all the laboratories concerned are to be congratulated, but special credit is due to the Bureau of Mines Laboratories, Ottawa, for the introduction of the mercury cathode, and later the Chemical Research Laboratory in Britain for their work on the activated cellulose column, both of which were first adopted for use on a multiple routine basis at the G.M.L.

Dr. Davidson concluded the report on his visit with the following words : " Present evidence appears to indicate that the Rand may be one of the largest low-grade uranium fields in the world." This conclusion has since been confirmed by the discovery of more uranium-bearing reefs than were at that time envisaged. Considerably larger low-grade deposits have since been shown to exist in Canada and are similar in character to the Rand and Orange Free State deposits except that they contain no gold. Other large low-grade deposits varying in size, grade, and difficulty of treatment have also been discovered in other parts of the world, but nevertheless it still appears that Dr. Davidson's comment remains substantially correct.

The commencement of experimental work at the G.M.L. to determine an economic method of extraction and recovery coincided with the despatch overseas of the initial samples at the conclusion of the visit by Professor Bain and Dr. Davidson towards the end of 1945. The first progress report was issued by the Laboratory in March 1946, and gave results of carbon and sulphide flotation tests on rich ore samples from the four selected mines. In February 1946, the Prime Minister, Field-Marshal J. C. Smuts, decided to appoint a Uranium Research Committee under the chairmanship of Dr. B. F. J. Schonland to co-ordinate action between the various investigations in progress, advise on further investigations, and to act as a clearing house of information both general and secret, and for this purpose to be accredited to the War Department of the United States and the British Ministry of Supply. Serving on this committee, in addition to the Chairman as President of the C.S.I.R., were the Director of the Geological Survey, the Government Mining Engineer, the Secretary for External Affairs, the Secretary for Mines, and the Director of the Government Metallurgical Laboratory, together with two members of the gold mining industry, one of whom was to be a technical specialist.

The first meeting was held on 8th March, 1946, at which the results of the preliminary test work were reported. A recovery of over 40 per cent. of the total uranium content present in the rich Blyvooruitzicht sample was reported in a carbon and sulphide concentrate of approximately 4 per cent. of the original weight. At this meeting authority was given for the appointment of a small Technical Sub-committee of the G.M.L. under the Chairmanship of the Director of the Laboratory, to deal with all matters of metallurgical interest and, in view of the secrecy requirements, to report solely to the Uranium Research Committee. Dr. O. A. E. Jackson, Mr. T. K. Prentice, and Mr. F. Wartenweiler were appointed to serve on this Committee which held its first meeting in April 1946, when the following reports were presented :—

Progress Report No. 1 : Ore Dressing.
No. 1 : Mineralogical.
No. 1 : Spectrochemical.
No. 1 : Electroscope determination of Uranium.