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DIRECTORATE OF
SCIENCE & TECHNOLOGY

Scientific and Technical Intelligence Report

Atomic Energy Activities in the Republic of South Africa

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March 1971

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ATOMIC ENERGY ACTIVITIES IN THE REPUBLIC OF SOUTH AFRICA

Project Officer
[redacted]

[redacted]
March 1971

CENTRAL INTELLIGENCE AGENCY

Directorate of Science and Technology
Office of Scientific Intelligence

PREFACE

This report reviews the production of uranium by the Republic of South Africa and its nuclear research efforts. The possibility that South Africa may enter the field of uranium isotope separation is considered also.

This report was prepared by the Office of Scientific Intelligence and coordinated with the Directorate of Intelligence. Information as of January 1971 has been used.

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ATOMIC ENERGY ACTIVITIES IN THE REPUBLIC OF SOUTH AFRICA

PROBLEM

To assess the atomic energy activities of the Republic of South Africa.

SUMMARY AND CONCLUSIONS

The Republic of South Africa currently has no capability for the production of fissionable material and there is no evidence of activity related to the development of nuclear weapons. In July 1970, the Prime Minister of South Africa announced the development of a new technology for isotope separation (U-235 enrichment) which is claimed to be economically competitive with other established methods. The Prime Minister announced also that a pilot plant was being constructed. Subsequently, the Chairman of the African Atomic Energy Board stated that the process is entirely new and is not gaseous diffusion, gas centrifuge, or the Becker jet nozzle method of isotope separation. Since the process was also stated to be of low capital cost but a heavy power user, gas chromatography also appears to be ruled out. As yet there is no information on the new process or on the exact location of the pilot plant.

South Africa has been a major supplier of uranium concentrates since 1952 and has produced approximately 75,500 tons of uranium oxide (U_3O_8). The United States and the United Kingdom have been its main customers. Presently, South Africa is also selling uranium to France and has sold small quantities to other countries. The uranium is being produced as a by-product of gold mining operations. Proven South African reserves are estimated at 220,000 tons of U_3O_8 in presently exploitable deposits. Current production is about 4,000 tons per year.

Although South Africa sold almost all the U_3O_8 that it produced through the end of 1970, about 4,600 tons have not been accounted for. It is not known whether this concentrate is being stockpiled or has been sold to other countries.

The nuclear research and development program of South Africa is small, except for the elaborate work related to raw materials production. The principal research facility is the National Nuclear Research Center at Pelindaba near Pretoria. A US-supplied high-flux research reactor, Safari-1, which went critical in March 1965, is at Pelindaba also. The reactor was initially operated at 6.6 MW but in February of 1969 was uprated to 20 MW.

The South African Electricity Supply Commission is planning to begin construction of a 3,000 MW(e) nuclear generating complex with a startup date in the mid-1970s of the first unit of 350-500 MW(e). Bids for the reactor are expected to be tendered in 1971.

DISCUSSION

BACKGROUND

Organization

In 1948 the Atomic Energy Act was passed to provide security and the machinery to control the exploitation of radioactive minerals and to establish the South African Atomic Energy Board. The Board was established in March 1949 and its initial operations were confined to administrative procedures concerned with mining, extraction and sale of uranium concentrates, the distribution and control of radioisotopes, mineral investigations, and a study of heavy water production. The Board had been preceded by the Uranium Research Committee, set up in 1946, which dealt primarily with uranium mining. In 1957, the detailed planning of an Atomic Energy Research and Development Program for the Republic was started and was completed in 1958 and was accepted by the government in 1959. The Program included research concerned with mining, extraction, processing and utilization of the country's major nuclear product– uranium. It was concerned also with practical manifestations of nuclear energy, namely, electric power production and radioisotope and radiation applications.[1, 2]

The Republic of South Africa is a member of the International Atomic Energy Agency (IAEA).

Personnel

The South African Atomic Energy Board has 841 employees of which 155 are scientists. The Chairman of the Board is Dr. A.J.A. Roux and Dr. T.E.W. Schumann is Deputy Chairman. There are 10 additional members of the Board with Dr. W.L. Grant as Director General and Dr. J.P.B. Hugo, Deputy Director General. [redacted]

URANIUM

Production

After negotiations between the South African Atomic Energy Board, the United States and the UK, the waste piles of four gold mines were set up for uranium processing. By 1951 contracts were drawn and 23 additional mines became uranium producers and South Africa became one of the world's leading uranium producers. In addition to shipments going to the United States and the UK, small quantities were also sold to Sweden, Japan, and France.

An estimated output of 4,000 tons of uranium oxide in 1970 represented about 20 percent of the Free World's total and placed the country third behind the United States and Canada among leading suppliers. The very low comparative cost of uranium recovery, by virtue of being a by-product of gold production, places South Africa in a favorable position to market uranium.

The Witwatersrand gold fields are the source of all uranium produced by the Republic of South Africa, although important fields have been discovered in Southwest Africa. The uranium mining operations and recovery plants are situated throughout a long mineralized belt. The occurrence of uranium in the gold-bearing ores of the Witwatersrand fields has been known since 1923, but it was not considered significant until 1944 when uranium became of strategic importance for the production of atomic energy.[3]

The feed material to South African uranium plants is the residue from gold extraction. Tailings deposited in slime dams or tailing dumps are also used to a considerable extent. The conventional uranium extraction process is much the same as that for gold involving agitation, precipitation, and filtration. Unlike the gold leaching process where cyanide is used, sulfuric acid is used in uranium recovery, which is produced on site, using the by-product pyrite from the gold ores as a source of sulphur dioxide.

The following South African companies are currently engaged in uranium mining and processing: Buffelsfontein Gold Mining Co. Ltd.; Harmony Gold Mining Company, Ltd.; Hartebeestfontein Gold Mining Company, Ltd.; Western Reefs Exploration and Development Company, Ltd.; Virginia (O.F.S.) Mining Company, Ltd.; and Zandpan Gold Mining Company, Ltd.; Blyvooruitzicht Gold Mining Company, Ltd.; Free State Saaiplaas Gold Mining Company, Ltd.; Vaal Reefs Exploration and Mining Company, Ltd.; West Rand Consolidated Mines, Ltd.; and Western Deep Levels, Ltd.[4] (The South African uranium processing facilities currently in operation are shown on table 1.)

South Africa by the end of 1970 produced 75,500 tons of U_3O_8 since mining operations started in 1952. Nearly 71,000 tons of this amount have been sold to other countries. (Table 2.) An additional 4,600 tons have been produced but are either held in reserve or have been sold to some unknown country. No information is available on the disposition of this concentrate.

Reserves

The Republic of South Africa possesses the world's third largest uranium reserves, preceded only by the United States and Canada. Total measured present reserves amount to approximately 220,000 tons of U_3O_8. Although of low grade, the deposits are associated with gold, pyrite, and small quantities of other metallic sulphides and can be mined economically as a by-product. The deposits are found in conglomerates of four continuous preCambrian systems, namely, the Dominion Reef, Witwatersrand, Ventersdsop and Transvaal.

The distribution of uraninite and gold in the conglomerates is intimately related to certain lithological and structural features of sedimentary origin. Evidence suggests that the uranium and gold were both deposited at the same time as the conglomerates, or soon after.

The conglomerates at several horizons in the Witwatersrand system are the principal sources of uranium in the gold mining operations of the Witwatersrand, Klerksdorp, and Orange Free State gold fields. These ore bodies account for about 90 percent of the country's total known uranium reserves. The balance consists of uranothorianite in carbonate.

In the immediate future, uranium will continue to come from developed areas within the Witwatersrand system or extensions of those areas and also, probably, from slimes and tailings ponds which are expected to yield increasing quantities as prices increase. There are however many areas beyond the borders of the gold field

TABLE 1

Current and Planned Uranium Producers

Company	Location[a]	Production started	Production		
			Plant[b] capacity	Yield lb/ton	Tons U_3O_8
W. Rand	Krugersdorp	1952	75,000	1.362	614
W. Reefs	Klerksdorp	1953	230,000	0.589	782
Harmony	Welkom	1955	225,000	0.310	313
Virginia	Welkom	1955	130,000	0.562[c]	404[c]
Hartes	Klerksdorp	1956	240,000	0.430	455
V. Reefs	Klerksdorp	1956	100,000	0.638	418
Buffels	Klerksdorp	1957	250,000	0.520	630
Saaiplaas	Klerksdorp	1963	d	...	...
Zandpan	Klerksdorp	1966	e	0.672	267
W. Deep	Carletonville	1969	70,000	...	...
Blyvoor	Carletonville	1969[f]	50,000	...	...
Plants under construction:					
Pres. Brand	Welkom	1971	200,000[f]		
W. Driefontein	Carletonville	1971	100,000		
Planned plants:					
South Vaal	Klerksdorp				

a Nearest town. Carletonville, Klerksdorp, and Krugersdorp are in the Transvaal; Welkom is in the Orange Free State.

b Tons per month of throughput.

c Includes production from Saaiplaas gold tails.

d No uranium processing plant. Saaiplaas contracted with Virginia to deliver high-grade uranium-bearing gold tails sufficient to produce 1,171 tons of U_3O_8. Contract completed by end of 1969.

e No uranium processing plant. 50,000 tpm milled pulp pumped to Hartes for gold and uranium recovery.

f Original plant of 175,000 tpm capacity which commenced production in 1953 was closed down in 1964 and salvaged. A new plant of 50,000 tpm capacity to process an upgraded fine fraction was completed and commenced production late in 1969.

TABLE 2

Uranium Production and Sales

CY	Production/tons	USAEC	[redacted]	France	Other	Total sales
1952	44.3	...		...	...	...
1953	567.6	278.1		...	...	462.5
1954	1,628.1	1,248.8		...	...	1,661.7
1955	3,290.6	2,520.1		...	...	3,072.1
1956	4,368.8	3,672.4		...	...	4,371.9
1957	5,709.2	4,355.8		...	...	5,606.3
1958	6,256.7	4,665.1		...	...	6,300.0
1959	6,428.6	3,720		...	17.6[a]	6,390.4
1960	6,437.1	3,900.8		...	...	6,677.0
1961	5,474	3,883		...	5[a]	5,002
1962	5,025	4,084		...	8[a]	4,569
1963	4,525	4,133		...	25[a]	4,158
1964	4,445	3,534		200	...	3,734
1965	2,942	1,932		500	...	2,781
1966	3,286	1,329		800	...	2,167
1967	3,214	...		1,100	800[b]	3,320
1968	3,883	...		1,400	825[b]	3,705
1969	3,979	...		1,500	500[b]	3,479
1970	4,000[c]	...		1,500	500[b]	3,481
1971	...	...		1,500	500[b]	...
1972	...	...		1,500	500[b]	...
1973	...	...		500	...	...

a Sold to [redacted] Sweden and France

b French option to purchase; believed purchased by France

c Estimated

which are geologically promising but which have yet to be specifically explored for uranium. One of these is Southwest Africa.

In late 1969, a major uranium discovery was reported in the Rossing area of Southwest Africa. Although no exact figures for these reserves are as yet known, it is estimated that this deposit contains from 500 million to one billion tons of ore. The grade of the ore is believed to be .04 percent U_3O_8. Exploration drilling and bulk sampling will continue until 1972 when the development stage will be reached. It is expected that the deposit will produce by 1975. The South Africans are tentatively planning a uranium mill with an input of 20,000 tons of ore per day by 1975 with a doubling of production by 1977.[5-8]

The ore body consists of an intrusive mass approximately five miles long by one mile wide and of undetermined depth. The Rossing uranium deposit is located in the center of a syncline facies of a late Proterozoic mobile belt which trends from Southwest Africa in the southwest to Zambia in the northeast over a distance of approximately 1,400 miles. The central position of the syncline is characterized by an intense granitization and pegmatitization of Proterozoic sediments. The ore occurs mainly in partly metasomatic pegmatites as uraninite and probably in granitized classic sediments such as allanite.

Depending on further exploration and analysis, the deposit could contain from 50,000 to 400,000 tons of U_3O_8 in reserves. However, it is likely that the lower figure is far closer to the actual reserves.

RESEARCH

Work was started on the design of a nuclear center at Pelindaba in 1960 and construction commenced in July 1961. The administration building and part of the reactor building were occupied in July 1963 while the chemistry building, accelerator, water purification works, and portions of the reactor engineering building were completed at the end of 1963.* (Figure 1.)

Safari-1

South Africa's only nuclear reactor is a research reactor called Safari-1. (Figure 2.) It is situated in the Pelindaba atomic research complex. This is an Allis-Chalmers designed tank-type reactor. It reached criticality in early 1965 and has operated at about 6.67 MW since that time, although it was designed for upgrading to 20 MW. This upgrading, by the addition of pumps and heat exchangers, took place in February 1969. The reactor uses MTR-type fuel elements, 90 percent enriched, and is cooled and moderated by light water. Replacement fuel elements are supplied by the UK as was a waste disposal plant.

Uranium Isotope Separation

On 20 July 1970, the Prime Minister of the Republic of South Africa announced that South Africa had discovered a new method of uranium isotope separation and that a pilot plant was being constructed. He further stated that the new process was economically competitive with those presently being used by Free World countries. No details of this plan were revealed and a tight security system was established for the plan's protection. A department entitled "Uranium Enrichment Corporation of South Africa, Ltd." was established.

Subsequently, Abraham Roux, the Chairman of the Atomic Energy Board, stated that the

*The research effort has been covered extensively in the *Thirteenth Annual Report*, Atomic Energy Board, Republic of South Africa, 1969, U.

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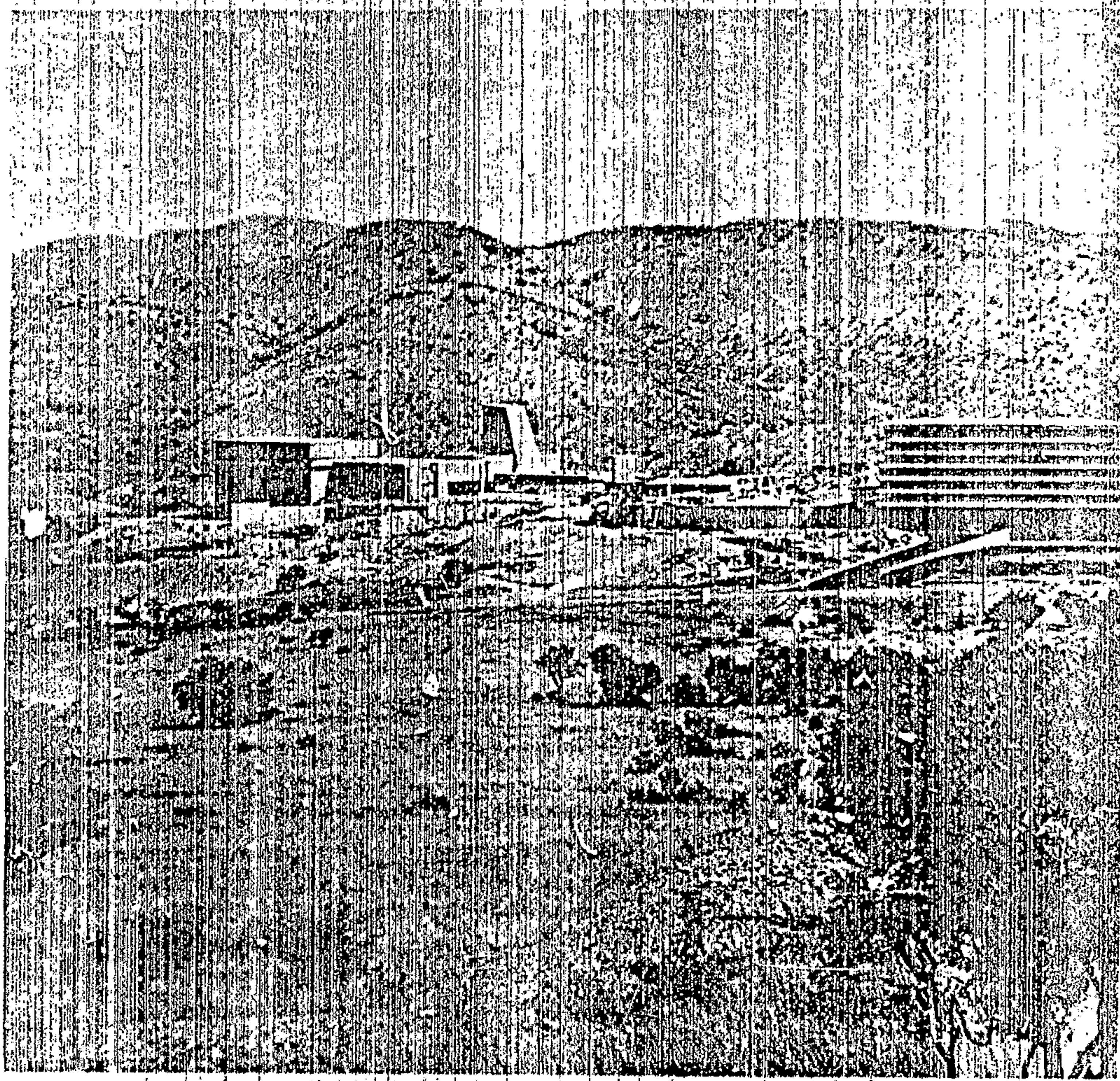

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Figure 1. Pelindab

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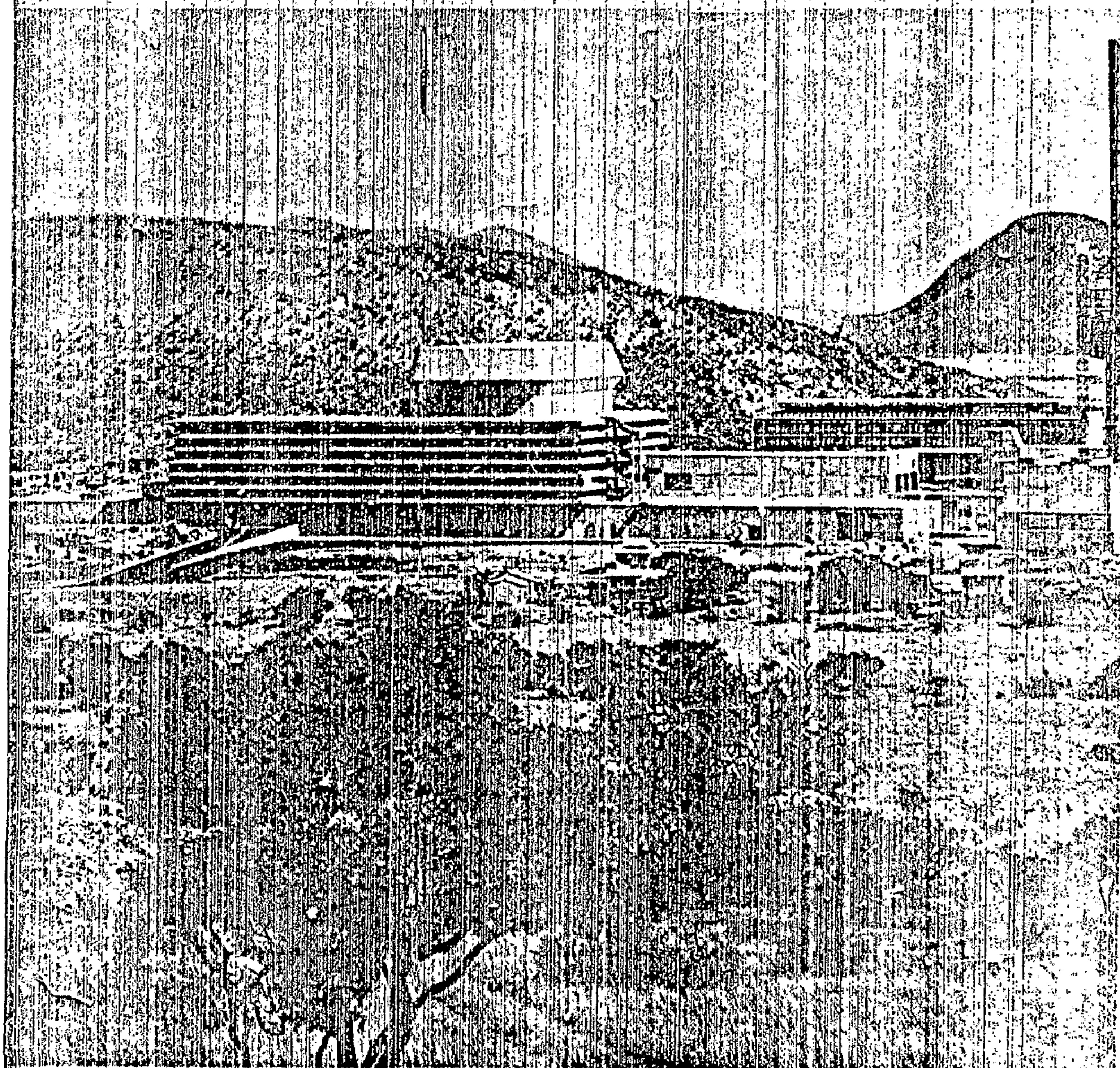

Figure 1. Pelindaba Research Center

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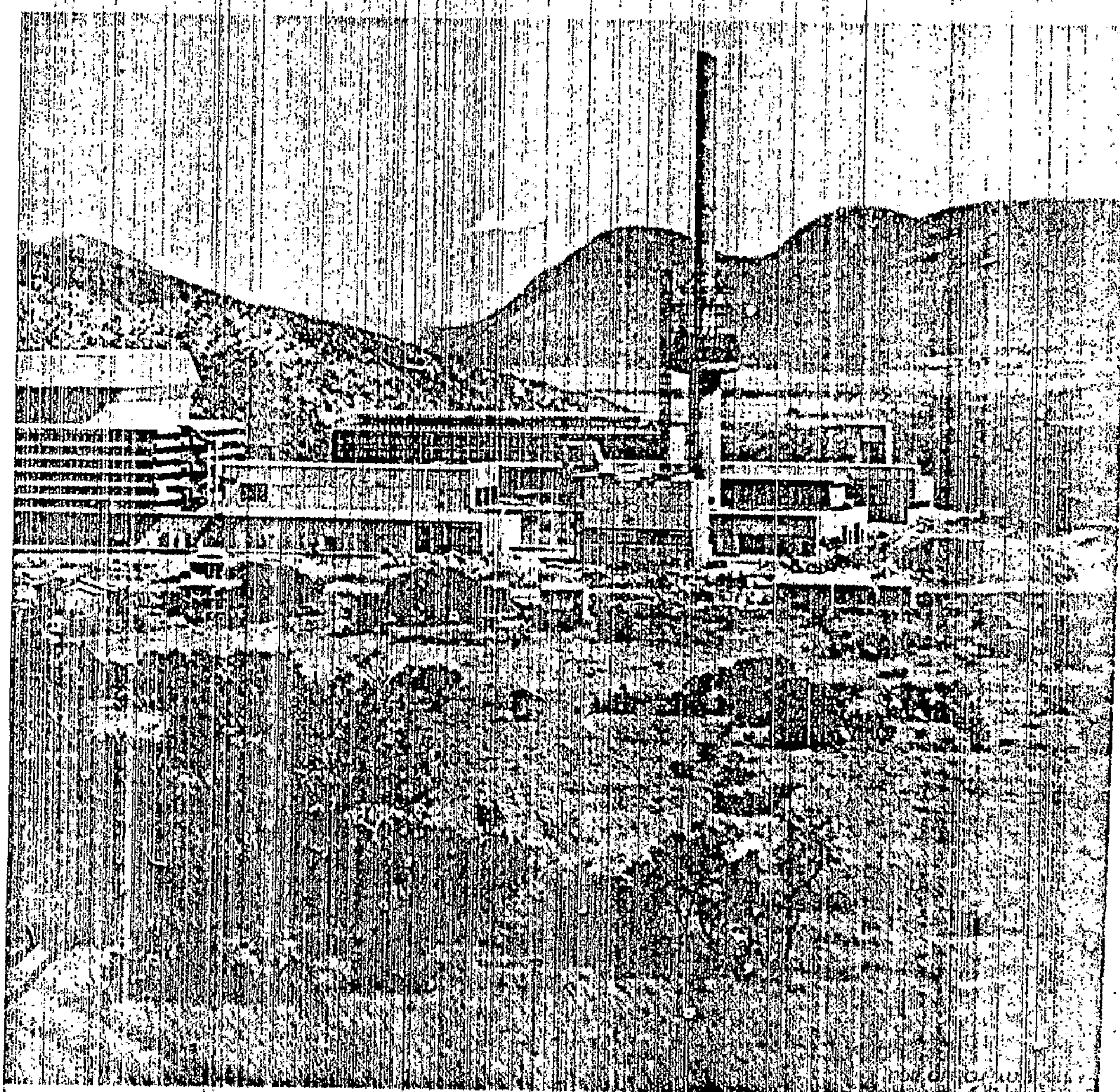

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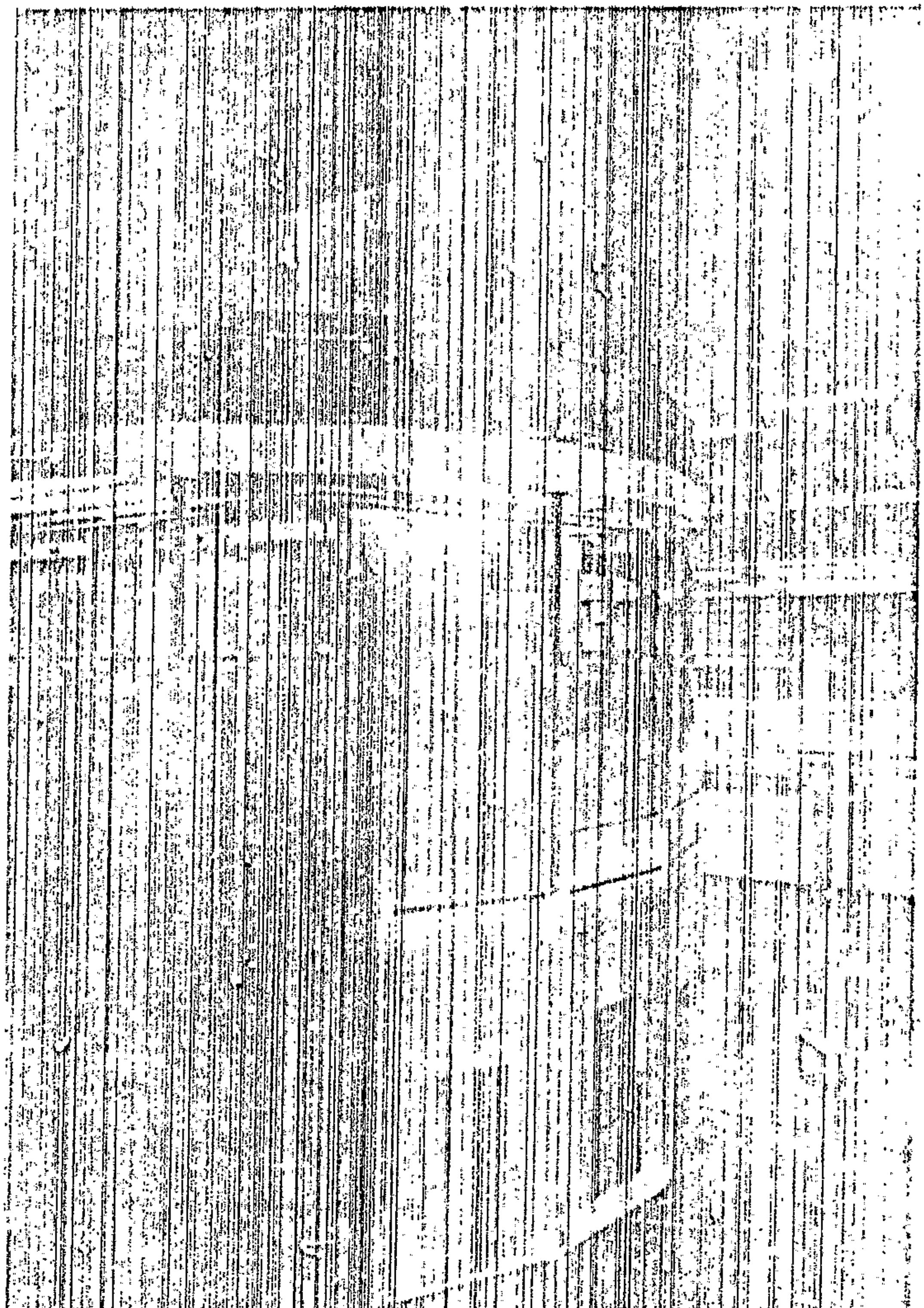

Figure 2. Sofari-1 Reactor

process is not gaseous diffusion, gas centrifuge, or the Becker nozzle method of isotope separation but an entirely new process on which the South Africans have been working for the past nine years. He further elaborated that it is low in capital cost but a heavy power user. Gas chromatography appears to be ruled out since that process is not a heavy power user. The fact that the process lends itself to small scale plants indicates that the process has a high separative capability. As yet, however, the process the South Africans plan to employ in their isotope separation techniques is not known.

A pilot plant for which $70 million has been allocated is currently under construction near Pelindaba, South Africa's atomic research center. The South Africans have indicated that they would be willing to locate a production facility in another Western country which has cheap electric power in return for financial assistance. Their objective is to have a full scale industrial plant in operation by 1978-80.[9-13]

Isotopes and Radiation

Considerable research has been carried out in the subjects of isotopes and radiation. Isotopes manufactured have been bromine 82, chromium 51, copper 64, gadolinium 159, gold 198, hafnium 181, lanthanum 140, potassium 42, rhenium 186, ruthenium 103, samarium 153, selenium 75, silicon 31, sodium 24, thulium 170, ytterbium 175, and zinc 65. In addition, an isotope method was developed to determine the uranium content of ammonium diuranate in the form of a slurry. An X-ray fluorescence method with radioisotope excitation was developed with the aid of a germanium detector with a view to the rapid determination of the uranium content of a sample.

Health and Safety

The health safety program has carried out studies on personnel dosimetry and made samples and smear analyses of the waste treatment building. Health physics work is carried out in the chemistry, engineering, and metallurgy buildings.

Radioactivity environmental studies were carried out in the environs of Pelindaba. A survey of gamma radiation levels is conducted once a year at about 170 points up to a distance of 30 kilometers from Pelindaba. All analysis revealed that radioactivity was within control limits.

After the French Pacific nuclear tests, a program was established to measure radioactive fallout, although it was found difficult to attribute fallout to any particular nuclear test.

Programs were also carried out in line with foot and eye protection and studies carried out on strontium-90 in the bone structure of the South African population and the quality of water from the far west Rand area.

Fundamental Studies

The Van de Graaff accelerator has continued to operate satisfactorily and refinements to auxiliary equipment have been made. An on-line computer has been installed also. Inelastic scattering cross-sections for various elements were measured. Gamma rays resulting from inelastic scattering were also investigated, and a theoretical physics program was actively pursued.

Activities in the field of chemistry included research into the radiolysis of aliphatic alcohols, solution polymerization, ion kinetics, the chemistry of zirconium and hafnium, as well as molten sodium studies.

Research in extraction metallurgy includes uranium leaching and mineralogy.

A cryogenic irradiation loop was installed and is used for radiation damage studies. Other materials investigation include electron microscopy internal friction, neutron diffraction, X-ray diffraction, neutron flux measurements, and surface area measurements.[14 15]

NUCLEAR POWER

South Africa is planning the construction of its first nuclear power station at Melkbosstraud near Cape Town. The station is expected to consist of three units of 350 MWe to 500 MWe each, with the first unit going into operation in 1978. Studies have been carried out on natural uranium reactors as well as enriched uranium thermal reactors, but as yet no decision has been made to the type of reactor to be built. Four foreign reactor construction companies are examining the possibility of submitting bids for the station. One German, one Canadian, and two British companies are expected to tender bids in 1971. Plans are also underway to study the electric power requirements of Natal with the possibility of constructing another nuclear power station in the first half of the 1980s.[16-20]

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APPENDIX A

South African Atomic Energy Board

Chairman

Dr. A. J. A. Roux

Deputy Chairman

Dr. T. E. W. Schumann

Members

Professor A. C. Cilliers
Professor of Physics
University of Stellenbosch

Mr. B. G. Fourie
Secretary for Foreign Affairs

Mr. C. J. F. Human
Federale Volksbeleggings

Mr. H. S. Mabin
Executive Director
Association of Chambers of Commerce of South Africa

Dr. T. F. Muller
Chamber of Mines of South Africa

Dr. S. M. Naude
President
Council for Scientific and Industrial Research

Professor S. F. Oosthuizen
Professor of Radiology
University of Pretoria

Mr. J. W. Shilling
Chamber of Mines of South Africa

APPENDIX A

Members (Continued)

Dr. R. L. Straszacker
Chairman
Electricity Supply Commission

Mr. U. J. Uys
Secretary for Mines

Director General

Dr. W. L. Grant

Deputy Director General

Dr. J. P. B. Hugo

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