"THE CASE FOR ENRICHMENT OF URANIUM IN AUSTRALIA"

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INTRODUCTION

Mr. Chairman, ladies and gentlemen, in opening the case for enrichment of uranium in Australia, I will present some information on the number of nuclear power stations in operation and under construction and the extent of use of uranium in nuclear power stations in the world today. I will explain what enriched uranium is, why it is being used instead of natural uranium and how it fits into the overall nuclear fuel cycle.

With this background, I will then consider the case for enrichment of uranium in Australia in detail and discuss finally the status of feasibility studies being carried out by Australian industry and government.

BACKGROUND INFORMATION

Nuclear Power Stations in Operation and under Construction

At the 30th June 1980 there were 230 nuclear power stations operating in the world and a further 232 under construction. The breakdown of these between the USA, the rest of the Western World, the USSR and the rest of the centrally planned economies is shown in Table 1.

The interesting features of this simple breakdown are that the USA represents almost half of both the capacity in operation and under construction in the western world, and the USSR about three-quarters of the capacity in operation and two-thirds of that under construction in the centrally planned economy region.

It is interesting to compare the numbers presented in this Table with similar numbers presented in previous years. This comparison in Figure 1 shows that although the overall nuclear program (including stations on order) has contracted in the USA, it has continued to expand in both the western world outside the USA and in the centrally planned economy region.

TABLE 1. Nuclear Power Units in Operation and Under Construction at 30th June 1980

Country or Group	In Operation No.	In Operation MWe	Under Construction No.	Under Construction MWe
Western World				
USA	71	52,202	74	80,526
Rest	123	59,176	111	94,604
Total	194	111,378	185	175,130
Centrally Planned Economies				
USSR	26	11,713	22	20,358
Rest	10	3,465	25	10,532
Total	36	15,178	47	30,890
World Total	230	126,556	232	206,020

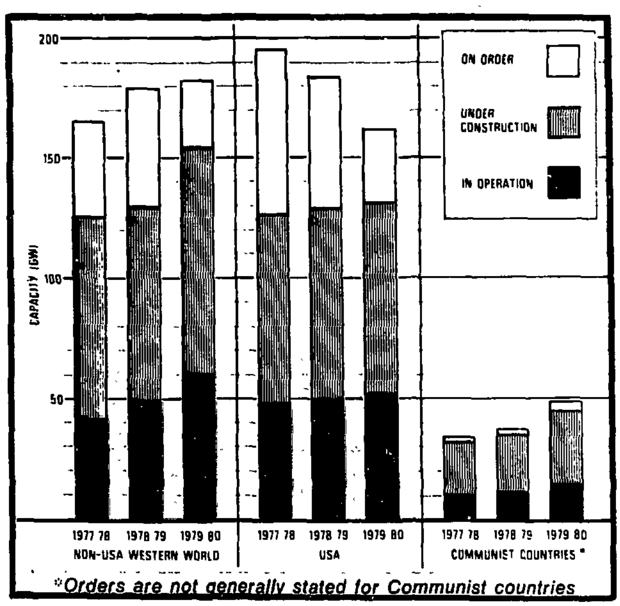

Figure 1. Comparison of nuclear power programs in the period 30 June 1978 - 30 June 1980.

The top ten nuclear countries in the world in terms of nuclear capacity in operation are listed in Table 2. You will note that the USSR ranks as number 3 after the USA and Japan, and that the German Democratic Republic is the other centrally planned economy country to make the list at number 10. These 10 countries represent 90% of the world's nuclear capacity in operation. However, many developing countries are making a significant investment in nuclear power, e.g. South Korea, Taiwan, Mexico, Brazil and India.

The percentage of electricity generated in 1979 in these countries is given at the right hand side of the table; it varied from 3.6% for the USSR to 22.3% for Sweden. Although the average figure for the USA was 11%, certain States in the north-eastern region depended heavily on nuclear power, e.g. Connecticut, 53%.

TABLE 2. List of Countries in Order of Nuclear Capacity in Operation at 30th June 1980

	Country	In Operation No.	In Operation MWe	Percentage of Electricity generated in 1979
1.	USA	71	52,202	11.0
2.	Japan	22	14,512	10.4
3.	USSR	26	11,713	3.6
4.	Germany, FR	11	8,555	11.2
5.	France	15	8,327	15.7
6.	UK	33	8,094	12.0
7.	Canada	10	5,490	9.4
8.	Sweden	6	3,741	22.3
9.	Switzerland	4	1,926	20.8
10.	Germany, DR	5	1,715	8.1
	Total	203	116,275	-
	World Total	230	126,556	

The Use of Uranium in Nuclear Power Stations

The amount of natural uranium required to provide fuel for immediate use in 1980 for the stations in operation and for new stations entering service in the western world was about 26,000 t. (i.e. no stockpiling for future use included). This is broken down into three groups in Table 3.

TABLE 3. Uranium Requirements for the Western World in 1980, tU

USA	11,500
W. Europe	10,900
Japan	2,300
W. World	26,400

The amount of uranium required annually is expected to double by 1990 when all of the stations referred to in the previous figures as "under construction" are expected to be in operation. The cumulative amount of uranium required by the western world up to 1990 is expected to be about 440,000 t. The value of this uranium, calculated at say A$60/kgU is $26 billion. Even if no more nuclear stations were constructed, the amount of uranium required to fuel all of those operating in 1990 for a further 15 years life would be about 1 million t. This represents a major on-going world industry for uranium mining, processing, upgrading and fuel fabrication in which Australia, with its presently-known reserves of relatively low-cost uranium of about 300,000 t, could play a major part.

Uranium Isotopes and the Use of Enriched Uranium

I will turn now to some basic information on why uranium is required to be enriched and why it is not used in its natural form in the majority of nuclear power stations.

Uranium has three naturally occurring isotopes. Isotopes are atoms of an element that have the same atomic number but different atomic weights or mass numbers. For uranium, these three are ^{238}U, ^{235}U and ^{234}U. All three are radioactive and emit alpha particles to form isotopes of the element thorium. Their structure and abundance are given in Table 4.

TABLE 4. Uranium Isotopes

Isotope	Protons	Neutrons	Abundance Wt.%
238	92	146	99.28
235	92	143	0.711
234	92	142	0.006

The fission or splitting of a uranium atom results in the release of energy. When a neutron hits a uranium atom under certain circumstances, the atom breaks up into two lighter atoms and an average of between two and three neutrons are also released. The combined mass of all the fragments is less than the mass of the original uranium atom plus the neutron and the small mass difference is converted into a large amount of energy. One gram of ^{235}U if fully fissioned would produce one MW-day of energy and about one gram of fission products.

Reactor fuel requires uranium which is highly purified and usually in the form of uranium oxide, UO_2. Reactors using natural uranium as fuel do not have the cost of enrichment but require a relatively large core and most require the use of heavy water, D_2O, as a moderator. This D_2O has to be obtained by enriching water in the deuterium isotope, which is an expensive operation.

If the uranium-235 isotope is enriched from 0.71 per cent to about 3 per cent, it is possible to build a nuclear power station of a required output with a smaller size of core and a lower capital cost, although the cost of the enriched fuel is greater than the cost of natural fuel. Most countries have chosen light water reactors using enriched fuel for their power programs. Accordingly, over 90 per cent of the present and proposed nuclear power reactors use enriched uranium fuel and this percentage is expected to remain the same over the next 20 years.

<u>The Place of Enrichment in the Nuclear Fuel Cycle</u>

Before enriched uranium fuel can be placed in a nuclear power station, the uranium has to be taken through a series of stages which form the first part of the nuclear fuel cycle which is illustrated in Figure 2.

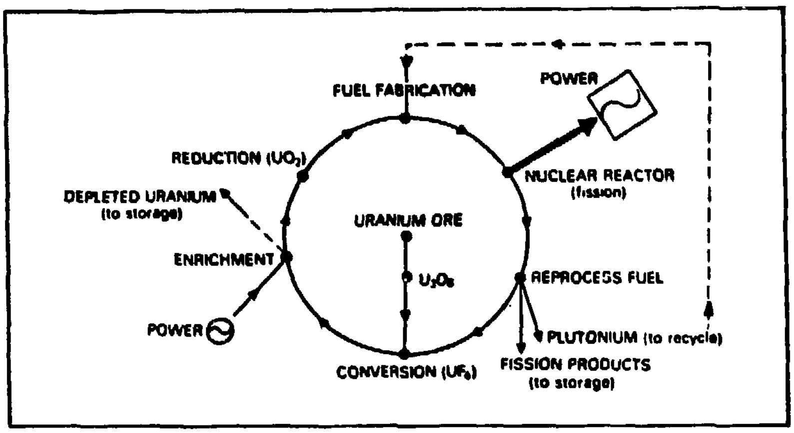

Figure 2. <u>The Nuclear Fuel Cycle</u>

Uranium ore is mined in underground or open-cut mines and processed into a uranium oxide concentrate called yellowcake, usually near the mine-site. The yellowcake is then purified to a very high degree at a refinery and converted into a gaseous compound, uranium hexafluoride, to enable it to be enriched. In an enrichment plant, the percentage of the ^{235}U isotope is increased from 0.71 per cent to about 3 per cent by a physical process using the uranium hexafluoride gas. The enriched gas is then reduced to a stable, solid uranium oxide. This oxide is fabricated into pellets and packed inside metal tubes to produce the fuel elements.

The fuel elements produce heat which is used to raise steam and produce electricity in conventional turbo-generators. The fuel elements are kept in the reactor for about three years on average and then replaced with new fuel elements. After discharge, the spent fuel elements are highly radioactive but still contain some useful uranium and an amount of a new element, plutonium, which has been formed by neutron capture in ^{238}U. The unused uranium and the plutonium can be recovered from the fuel and processed for re-use in new fuel elements if required. The waste radioactive fission products can also be separated from the uranium and plutonium and converted into solid blocks for burial deep underground to prevent them harming mankind in the future. Alternatively, the spent fuel elements can be stored and if not required for recovery, could ultimately be encapsulated and buried deep underground.

How Uranium can be Enriched

The five major methods which have been used for uranium enrichment are listed in Table 5.

TABLE 5. Major Methods for Uranium Enrichment

Gaseous Diffusion
Gas Centrifugation
Laser Separation
Chemical Exchange
Aerodynamic Separation

Of these, gaseous diffusion has been used since the 1940s in large government plants and, up to a few years ago, was the only process used for enriching uranium on a large scale.

Gas centrifugation, although tested out on a small scale in the 1940s, was not developed widely or on a commercial scale until the last 10 years.

Laser separation and chemical exchange are two processes which have come into prominence only in the last 10 years for uranium enrichment, but both are still in the development phase.

Aerodynamic separation processes in which a gas containing uranium molecules passes through a nozzle or a vortex have also been taken in recent years to a large development scale in the FRG (nozzle) and South Africa (vortex method).

I will discuss the basic principles of the first two of these processes as a background to the case for enrichment in Australia.

Gaseous Diffusion

The principle of enrichment by gaseous diffusion is that the lighter molecules in a mixture of light and heavy gaseous molecules diffuse through the holes in a porous solid membrane slightly faster than the heavy molecules. The gas used is uranium hexafluoride, UF_6, and the holes in the porous membrane are some five to fifty times the diameter of the UF_6 molecules.

The separation achieved between the $U^{235}F_6$ and $U^{238}F_6$ molecules is small in a single stage and is related to the average velocities of the molecules, which in turn are proportional to the square roots of the masses, and this leads to a separation factor of 1.0043. This is a relatively low value which means that in a single stage for example, the natural uranium hexafluoride feed of 0.711 per cent ^{235}U would only give a product of a little less than 0.713 per cent. Hence, over 1,000 successive stages are required to increase the ^{235}U percentage to 3 per cent.

The process in each stage is illustrated in Figure 3, in which the feed gas at high pressure is divided into a slightly enriched stream and a slightly depleted stream. The combination of stages into a group called a cascade is shown in Figure 4. A compressor is required before each stage and a heat exchanger to cool the gas before it enters the barrier section. Each main compressor in a large gaseous diffusion plant can require 3 MW energy input.

In a practical enrichment plant, the relative quantities of natural feed, enriched product and depleted reject material (known as tails) to provide the annual reload fuel for a 1000 MWe pressurised water reactor station operating at 70% load factor are shown in Table 6.

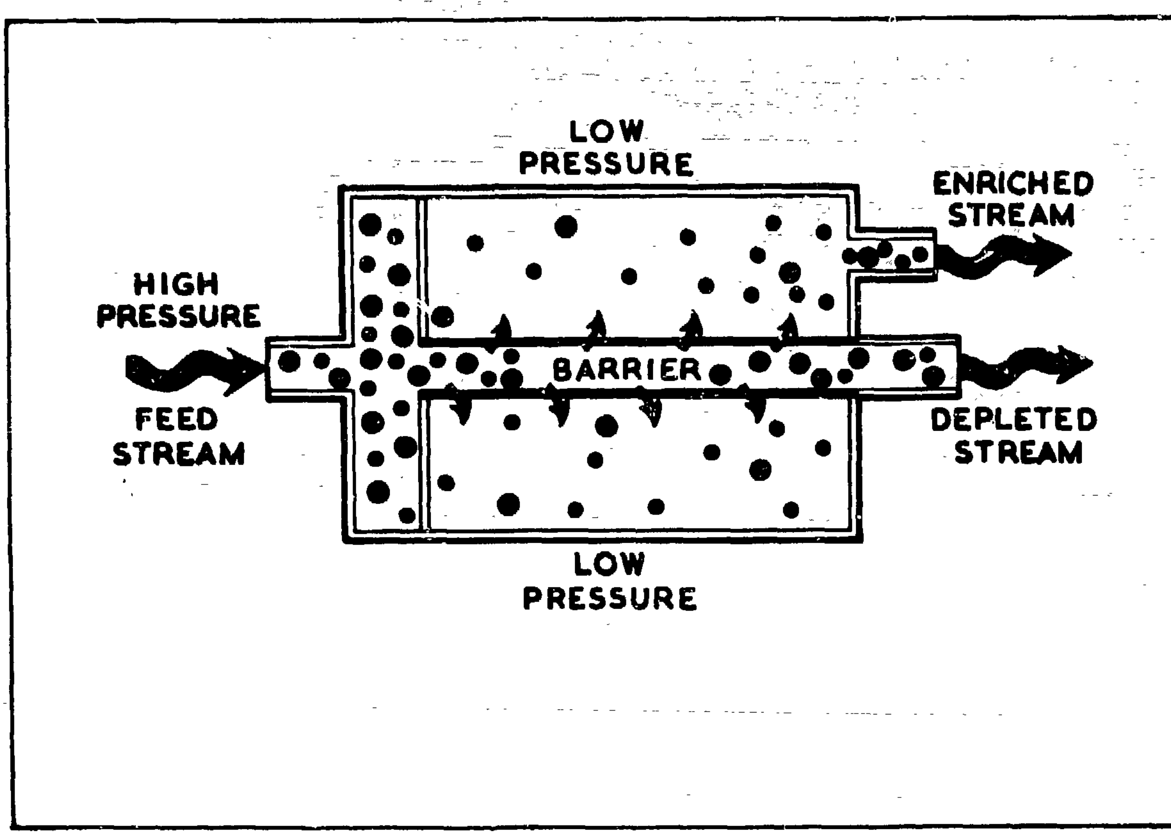

Figure 3. Gaseous Diffusion Process

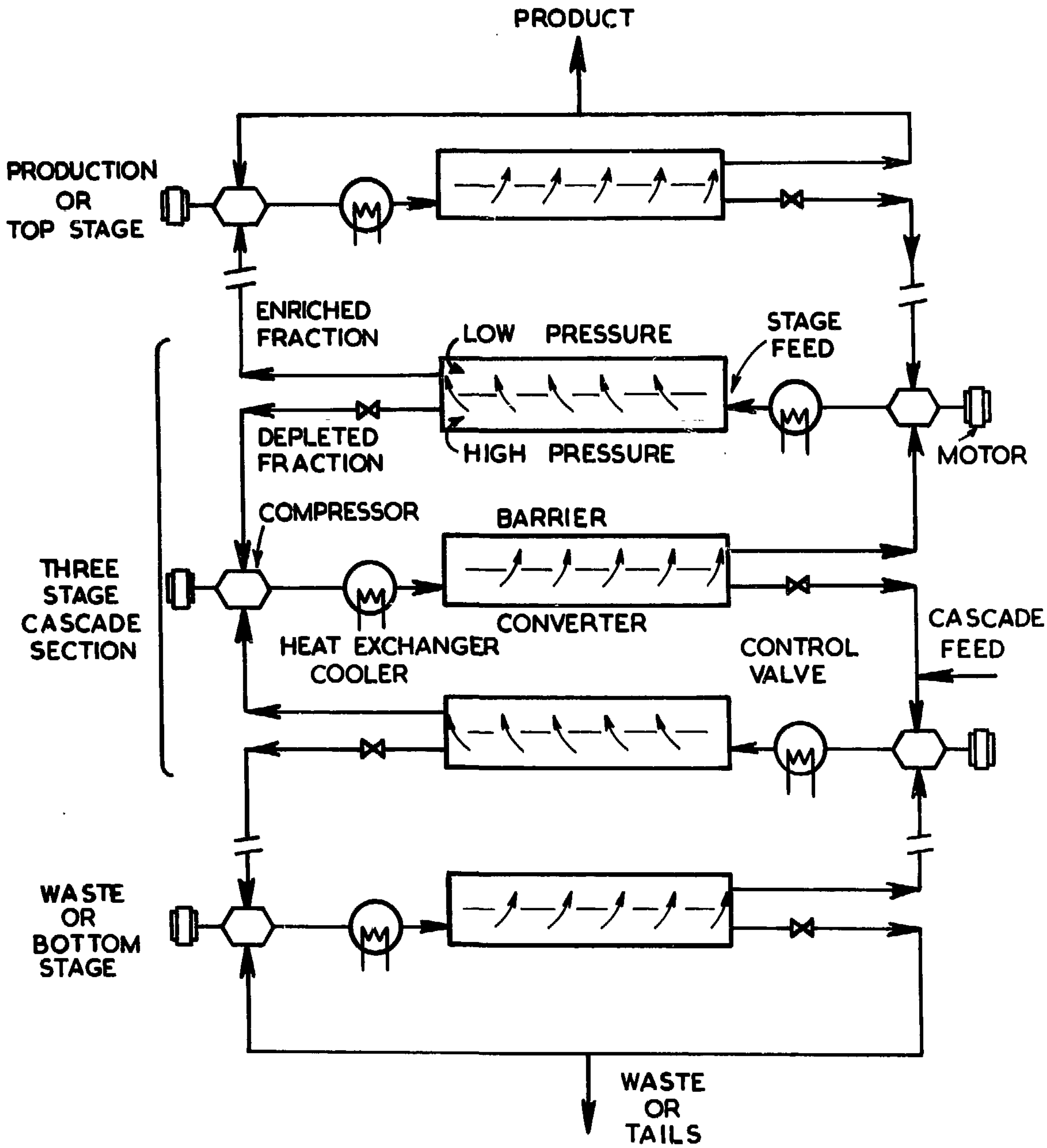

Figure 4. Cascade of Gaseous Diffusion Stages

TABLE 6. Mass Balance in Enrichment Plant

Feed	0.711%	$^{235}UF_6$	Mass	213t
Product	3.15%	$^{235}UF_6$	Mass	34t
Tails	0.25%	$^{235}UF_6$	Mass	179t
Work required =	139,000	Separative Work Units		

The amount of work done in enriching uranium is expressed in separative work units or SWUs which take into account the amount of enrichment and depletion achieved and the mass flow. Under the above conditions it would require 4.1 SWUs to separate 1 kg of 3.15% product from 6.3 kg of natural feed whilst producing a depleted stream of 5.3 kg at a 0.25% assay.

When we speak of a 1 million SWU/a enrichment plant we therefore mean a plant with a capacity suitable for providing sufficient enriched uranium to reload about 7 modern 1000 MWe nuclear stations each year.

The USA operates three large diffusion plants at present which have a total available capacity of over 25 million SWU/a. France has nearly completed the construction of the largest single diffusion plant in the world with a capacity cf 10.8 million SWU/a. The capacity of all of these plants would supply for example, the needs for reload fuel of about 210,000 MWe of nuclear stations which will be reached before 1985 in the western world.

A photograph of the new plant in France is shown in Figure 5. The plant is made up of the four main buildings in the background and the two large cooling towers to dissipate nearly 3000 MW of heat. In the foreground are the four 940 MWe pressurised water reactors of the Tricastin nuclear station which will supply the electrical energy to the plant and the surplus to the French grid.

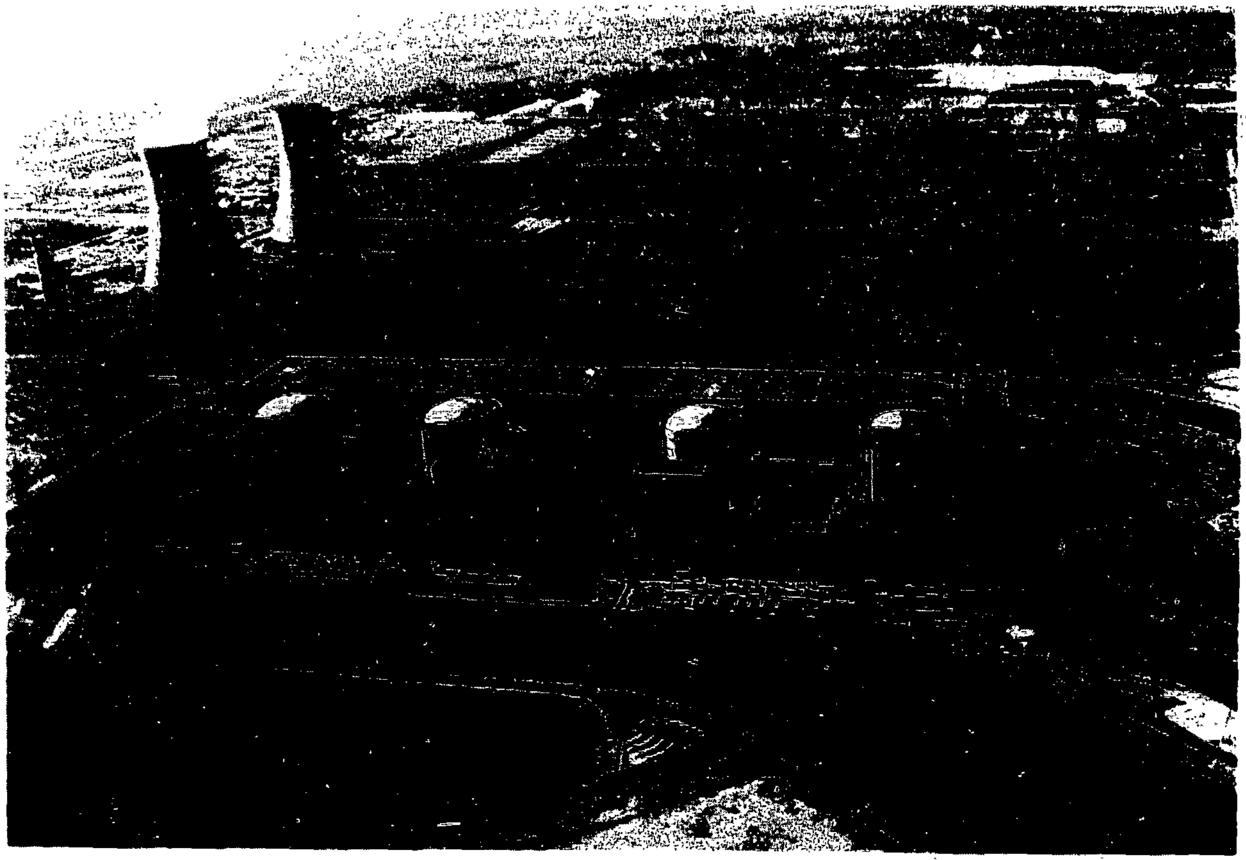

Figure 5. Gaseous Diffusion Plant at Tricastin, France.

Gas Centrifugation

The principle of the gas centrifuge is based on the separation effect on a mixture of isotopes by a strong centrifugal field in a rotating cylinder, combined with the cascading effect of countercurrent circulation of the gas. Figure 6 shows a simple centrifuge with the gas fed into the centre, and product and waste withdrawn by scoops at each end.

The separation factor in a single centrifuge can be between 1.2 and 1.5, which is very much larger than the 1.0043 for gaseous diffusion separation. This means that, in theory, only about 10 stages in cascade are required to obtain a 3 per cent ^{235}U product, compared with 1,000 stages for gaseous diffusion. However, this advantage is counteracted by the smaller throughput or separative work output of a single centrifuge compared with a single diffusion stage. Accordingly, many thousands of centrifuges must be cascaded in parallel to obtain a large commercial output. One other significant

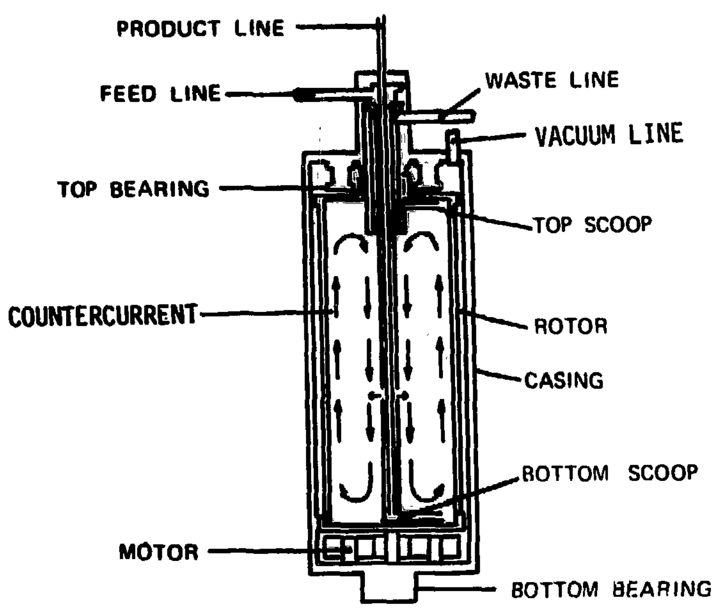

Figure 6. Countercurrent Centrifuge

advantage of the centrifuge process is the much lower power consumption, only 5 to 10 percent of that required by gaseous diffusion.

In order to increase the performance of a centrifuge the main factors which can be varied practically are the length and the speed of rotation. Hence it is advantageous to make the machines longer and to spin them faster. The problem is to select the optimum material for the rotating tube to withstand the enormous g-forces and the possible attack by UF_6 gas, and yet be able to mass-produce them cheaply. The two basic practical approaches are shown in the next two figures.

Figure 7 shows a building full of the relatively small type of centrifuge developed in the European countries, Japan and Australia. This shows an early demonstration cascade at Almelo in the Netherlands built and operated by the FRG in the early 1970s.

Figure 8 shows USA prototype jumbo centrifuges in a demonstration cascade at Oak Ridge. These are relatively large and expensive, and claimed to have about 10 times the output of the best small machines. Only time will tell which design philosophy proves to be best in the large centrifuge plants of the future. The largest plants presently in operation are 400,000 SWU/a plants in the UK and in the Netherlands. Larger plants are under construction in those countries and a 2.2 million SWU/a plant is under construction in the USA.

Other processes

Enriched uranium can be produced by several processes using lasers to interact selectively with the ^{235}U atoms, and by several processes using the small differences in chemical properties between ^{235}U and ^{238}U ions and compounds in solution. However, all of these processes are still in the research and development phase and it may be many years before large production plants can be constructed using these principles. Potential advantages of the laser processes are claimed to be the lower energy consumption than even the

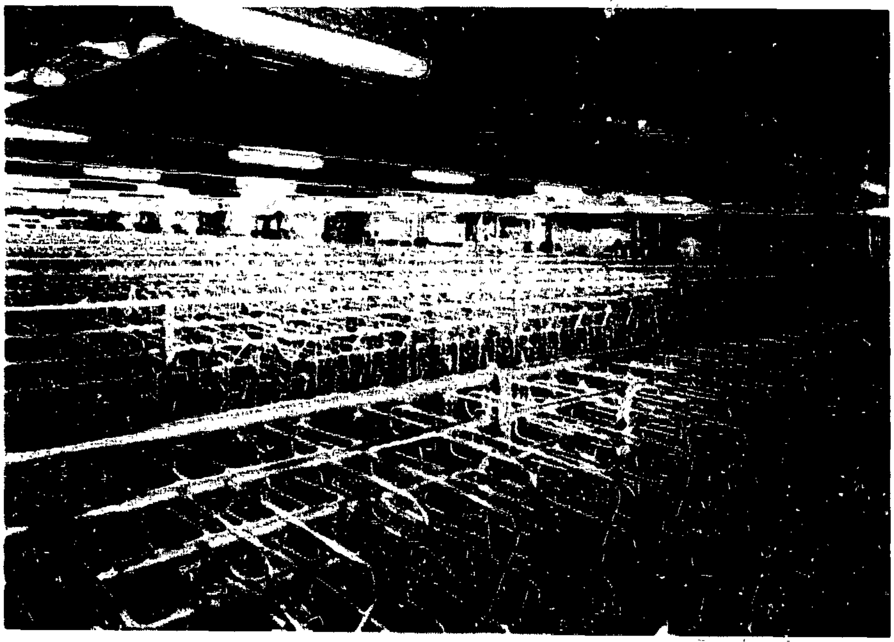

Figure 7. Centrifuges in Almelo Plant

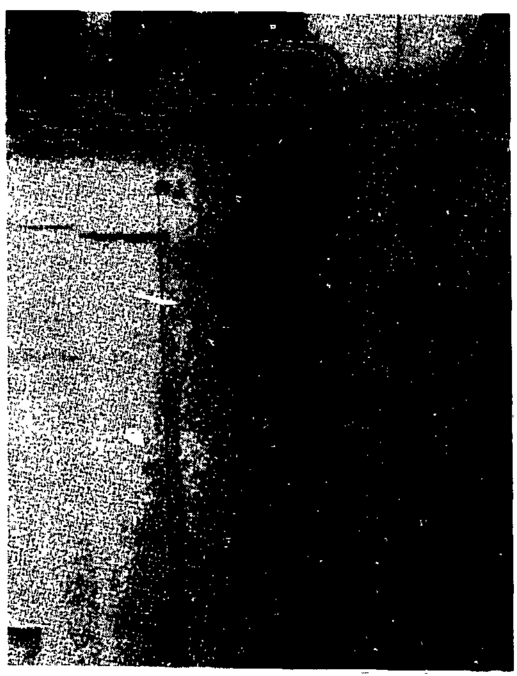

Figure 8. Advanced Equipment Test Facility, Oak Ridge, Tennessee.

centrifuge process and the ability to produce a 3% product without cascading although this will require a large number of units in parallel. Advantages of the chemical exchange processes are the lower energy consumption than the diffusion process (but not the centrifuge process) and the relatively simple chemical equipment involved.

The aerodynamic processes developed by the FRG (nozzle process) and South Africa (vortex or "helikon" process) are regarded by most observers in the western world as having the serious disadvantages of high energy consumption and limited development potential.

The final Table in this background section summarises the processes which I have outlined and their status:

TABLE 7. Present Status

Process	Sepn. Factor	Stages	kWh/SWU	Status
G.D.	1.0043	1000	2400	Large commercial
G.C.	1.2-1.5	10	100-200	Small commercial
LIS	2-5?	1+	10?	R & D
CE	1.0015-1.0030	>1000	200-600	R & D
Aero-dynamic	1.015-1.025	> 100	>3000	R & D

THE CASE FOR URANIUM ENRICHMENT IN AUSTRALIA

The case for uranium enrichment in Australia can be considered under the five main headings given in Table 8.

TABLE 8. Outline of the Case

- Need for additional enrichment capacity
- Added value
- Potential profitability
- Increased employment and industrial opportunities
- Retention of depleted uranium

The Need for Additional Enrichment Capacity

The estimation of the extent of the need for additional enrichment capacity in the future is one of the most important, and most difficult, parts of the overall assessment of the feasibility of enrichment in Australia.

An estimate has to be made first of the way in which nuclear capacity will increase over at least the next 20 years. Then an estimate has to be made of the requirements for uranium and enrichment services to supply the nuclear fuel. Finally, the required enrichment capacity must be compared with the existing capacity and any increases which have been firmly committed. This provides an estimate of the future uncommitted world market for which any Australian plant would be competing with expanded existing plants or new plants in other countries. Several international and national organizations in both the government and private sectors make these estimates regularly and there is a general consensus that nuclear power capacity will increase steadily over the next 20 years and that additional enrichment capacity will be required in the 1990s. Let us now look at some quantitative estimates made by the AAEC recently to illustrate these points.

Table 9 presents estimates of installed nuclear capacity in the western world based on the summation of individual countries' programs using available information on plant installation programs, future electricity demands and potential alternative sources of generation.

TABLE 9. Estimates of Installed Nuclear Capacity (GW)

Year	USA	Japan	W. Europe	W. World
1980	55.4	14.5	44.4	122.6
1985	106	21	94	243
1990	130-145	30-40	125-160	320-390
2000	150-200	60-90	180-285	460-710
2010	150-320	90-130	235-390	580-1080

The extent of uncertainty beyond 1990 is given in the range of estimates, which takes into account possible changes in the price of oil and possible environmental constraints on the use of nuclear and fossil fuels for energy generation.

Let me focus attention now on the best estimate at the present time for the increase in nuclear capacity to the year 2000. Table 10 illustrates the conversion of this estimate into our best estimate for the annual requirements for enrichment services.

TABLE 10. Annual Requirements for Enrichment Services in Millions of SWUs (AAEC Best Estimates)

	1980	1985	1990	1995	2000
USA	8.6	13	16	17	19
W. EUROPE	6.6	10	16	20	22
JAPAN	1.9	2	4	6	8
W. WORLD	17.5	26	39	48	57

NOTE: Estimates at 0.2% ^{235}U enrichment tails assay

For comparison with these requirements we should now look at the maximum possible production from enrichment plants presently operating and under construction as listed in Table 11.

TABLE 11. Estimated Maximum Production from Enrichment Plants in Operation and Under Construction (M SWU/a)

	1980	1985	1990	1995	2000
USA GD	10.8	21.6	25.6	25.6	25.6
GC	-	-	1.1	2.2	2.2
FRANCE	4.0	10.8	10.8	10.8	10.8
URENCO	0.4	2.0	2.0	2.0	2.0
USSR*	3.9	3.4	2.4	0.1	0.1
OTHERS	-	0.1	0.3	0.3	0.3
TOTAL	19.1	37.9	42.7	40.4	40.4

* Likely supply to western world under contract.

The values in this Table represent the maximum possible production assuming that the USA has the required power supplies to operate its plants, and that contracts with the USSR will not be extended into the 1990s now that Europe has its own plants and the Comecon nuclear program is expanding rapidly.

Figure 9 compares the best estimate of enrichment requirements with the estimate of maximum available enrichment production. It is clear that there will be an excess of capacity over requirements in the 1980s, and that new capacity will be required in the early 1990s. While this method of market assessment gives a broad indication of the future balance of supply and demand it is over-simplified. It does not take into account such factors as

- regional balances of supply and demand
- contract conditions
- price

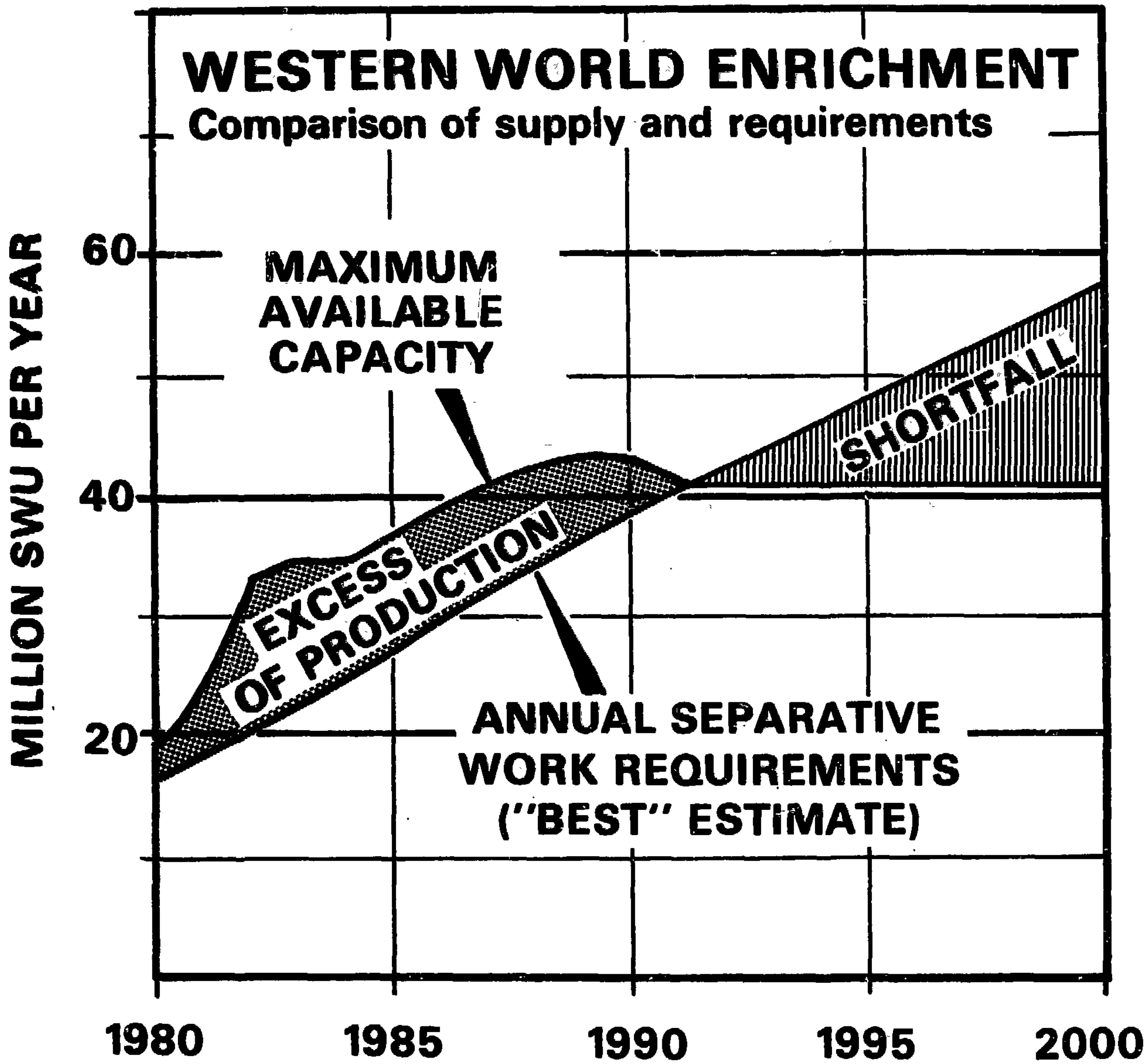

Figure 9. Comparison of Enrichment Capacity and Requirements

- political and national influences
- security of supply
- diversity of supply
- stockpiling policies

One example is that US utilities have not entered into contracts with overseas suppliers and this tendency may continue. Some customers consider diversity and security of supply more important than price, and will want to consider domestic production and stockpiling to prevent interruptions to supply. An expansion in nuclear power programs in the 1980s will bring forward the date new capacity is needed, a reduction in programs will have the opposite effect.

The most satisfactory resolution of the supply - demand balance for the entry of Australia as a new enrichment supplier in the 1990s is to announce a commitment in principle to an enrichment plant subject to satisfactory contracts being negotiated. While a detailed feasibility study is being carried out, the future market will be examined in detail in parallel with technical and economic studies in the same way that the new projects started for the EURODIF plant in France and the expanded URENCO plants in the UK, Netherlands and FRG. If new contracts cannot be negotiated in the 1980s for supply in the 1990s, then it is clear that a plant will not be built in Australia.

Added Value

Australia has about 16 per cent of the known low-cost uranium reserves in the western world. These reserves are only now being developed on a large scale. By the end of 1981, Australia is expected to have three uranium mines in operation producing at the rate of over 4,500 t U per year. By 1990 Australia could be exporting 9,000 t U per year.

The export value of uranium is more than doubled if the uranium concentrate or yellowcake is converted into UF_6 and enriched to the level of about 3% required for light water reactor fuel elements. I will illustrate this in Table 12.

TABLE 12. Calculation of Added Value

5.5 kg U, natural uranium @ \$60/kgU	=	\$330.00
5.5 kg U, converted to UF_6 @ \$5/kgU	=	27.50
4.3 SWU, enrichment services @ \$120/SWU	=	516.00
∴ 1 kg U, 3% ^{235}U as enriched UF_6	=	\$873.50

Added value = \$543.50 (or 1.65 x \$330.00)

If 9,000 t U were exported from Australia as yellowcake in say the year 1990, it would have a value of \$630M, assuming a price of \$70 per kg U for illustrative purposes in present dollars. If all of this were to be enriched in Australia the added value on the above assumptions would be \$888M in one year.

However, it is unlikely that all customers for Australia's uranium would wish to have it enriched in Australia because of existing long-term contracts elsewhere, but the potential is there to significantly increase our export income. If it is assumed that at least one-third of our exported uranium could be expected to be upgraded in Australia in the early 1990s, this would correspond to a plant capacity of about 2 million SWU per year and generate an added value of about \$300M per year in present dollars.

Potential Profitability

In order to assess the profitability of a major new project it is necessary to know the timing of the project, the capital and operating costs for a chosen size of plant, the price which can be obtained for the product, the method of financing, e.g. by equity or loan funds or both, and so on. Assumptions have usually to be made on all of these factors and a sensitivity analysis carried out to determine how the profitability is affected by changes in the factors. The AAEC has made studies of this kind over several years in association with overseas owners of technology and on its own.

I am not able to present to you today a detailed economic analysis of an enrichment plant project in Australia. The detailed information which the AAEC has available to it on overseas plants has been supplied under commercial confidentiality agreements with overseas owners of technology. In addition, the government has asked for the advice of major Australian companies on the commercial viability of an enrichment industry and I shall refer to this later. I therefore do not wish to pre-empt the detailed assessment by these companies.

However, I can generalise at this point and restate the view that the AAEC has held for several years and publically stated in its Annual Reports. It will be possible to obtain a rate of return that will be acceptable to industrial investors, and that will be at least as good as that shown by chemical and manufacturing industry in Australia in recent years. The basic assumptions in these studies have been that

- a plant is built in stages over a number of years to match the market demand;
- firm long-term contracts are obtained at market prices typical of those achieved by such organizations as EURODIF and URENCO in recent years;
- advance payments are obtained from customers, as has been the practice for many years, these payments typically being 10% of the value of a contract;
- financing is by a combination of debt and equity with normal commercial interest rates being paid on debt capital.

If a centrifuge enrichment plant expanded progressively over a number of years is taken as an illustrative model one would expect a capital cost of about $500M for each increment of 1 million SWU per year capacity including interest during construction. The value of the output from each 1 million SWU per year addition would be of the order of $120-150M per year. The value of a 10% advance payment for a ten-year contract would also be $120-150M and contribute significantly to the initial financing of each increment. Assuming 20% equity and 80% debt financing the equity requirement for each increment would then only be about $70M and it is considered to be feasible to raise a large part of this on the Australian market. It is also feasible to obtain a substantial part of the debt financing from the customers either directly or supported by loan guarantees.

One good indication that these illustrative figures are in the right ball-park and that a case has been made for potential profitability will be if the advice of Australian industry to the Government is that a detailed feasibility study should be carried out substantially at industry expense. Unfortunately, the results of the industry report to government have not yet been announced, but I am confident that they will support my statement.

Increased Employment and Industrial Opportunities

The commitment of about $500M capital expenditure every two to three years, for example, for an expanding centrifuge enrichment plant project, would provide a large number of new jobs for construction workers, plant operators, and workers in associated manufacturing and materials supply industries. As an indication, about 200 direct operating and support staff would be required per increment of 1 million SWU per year. An average construction workforce of about 500 would be required over at least a 10-year period with a similar number in manufacturing industry providing the major components required. For a model of a large diffusion plant project scheduled over some 8 years a considerably larger construction workforce would be required. With the latter technology a large electrical supply of over 2000 MW would be required to be installed over 8 years. It would therefore be appropriate to include a contribution for the construction and operating workforce for this electrical power generation capacity and for coal mining and processing capacity since it would almost certainly be based on coal as a fuel. This would require an additional 200 employees per million SWU per year enrichment capacity.

Overall we can estimate for a centrifuge plant project expanding in capacity, for example, from 1 million SWU per year in 1990 to 5 million SWU per year by 2000, a total construction and operating workforce expanding from about 250 in 1985 to 1500 in 1995 and stabilising at about 1000 in the year 2000. For a major diffusion plant project the numbers would be considerably higher due to a larger contribution from the electricity production industry. The provision of infrastructure for such a major project, i.e. roads, services, housing, would involve many hundreds of additional jobs.

It should be stressed that a large proportion of the total capital cost of such a project is in the plant equipment, e.g. centrifuges and associated mechanical, chemical and electrical equipment, and it is expected that a substantial part of this will be provided by Australian industry. With a diffusion plant it is also possible that a substantial part of the total capital investment could be provided by Australian industry, with the possible exception of the large compressors for which there is no comparable aerospace manufacturing experience in Australia.

Retention of Depleted Uranium

If uranium is exported as yellowcake and enriched overseas, the depleted uranium is normally retained by the customer or by the owner of the enrichment plant. This depleted uranium contains about 0.2 to 0.25 per cent ^{235}U and 99.8 per cent ^{238}U. It therefore contains about 30 per cent of the ^{235}U initially present because it is uneconomic to deplete it to a lower level with present technology.

In the future, the development of more efficient enrichment methods may enable this uranium to be depleted still further, which will save the mining of some additional natural uranium.

Of greater importance in the long term is the value of the ^{238}U as a fuel for advanced breeder reactors, which are likely to be constructed in significant numbers in the 21st century and gradually replace the conventional light water reactors. Depleted uranium would be used in both the fuel in the core in the form of a mixed uranium-plutonium oxide, and as the material in the outer regions of the reactor to breed more plutonium.

If an enrichment plant is built in Australia about 4.5 kg out of every 5.5 kg uranium produced as yellowcake would be retained in Australia as depleted uranium. This resource could be available for reworking if more efficient technologies are developed in the future and sold as depleted uranium when a market develops for fast breeder reactors.

Environmental Issues

The environmental impact of a substantial uranium enrichment industry will largely be governed by the impact of the construction phase and the effects of a typical large industrial development on a region rather than the impact of radiation or radioactive substances. The feed to an enrichment plant is highly purified natural UF_6 and the product and tails are highly purified enriched and depleted UF_6 respectively. The radioactivity levels from the uranium will be negligible outside the containers and equipment in the plant.

The use of gaseous diffusion technology will have a larger overall environmental impact than the use of centrifuge technology in that a substantial electricity generating capacity will be required. This will almost certainly require the mining and handling of a substantial quantity of coal with its associated environmental impact and substantial gaseous emissions from the power plant. For example, a 6 million SWU per year diffusion plant will require about 1600 MWe produced from 5 million t coal per year. There is an increasing awareness of the environmental impact and risks associated with the large scale combustion of coal and oil - the carbon dioxide problem with its potentially damaging long term effects on climate, acid rain and particulate fall-out, etc.

As with uranium mining, however, there are those who would seek to prevent an enrichment industry being created in Australia on broader environmental considerations related to the overall nuclear fuel cycle and in particular the questions of diversion of uranium for non-peaceful purposes and the long term disposal of nuclear wastes. Such issues were canvassed in the first report of the Ranger Uranium Environmental Inquiry (the Fox Inquiry) and carefully weighed by the Government before it made its decision to proceed with an uranium mining industry - the findings are equally applicable to any decision to proceed with an enrichment industry.

STATUS OF FEASIBILITY STUDIES

Over a number of years the Australian Government, largely through the AAEC, has carried out several feasibility studies on enrichment in Australia. The operation of an enrichment plant would be consistent with the government policy of encouraging the maximum possible upgrading of mineral exports.

Although the Government, through the AAEC, has been developing its own enrichment technology, it has been recognised that there could be advantages in acquiring both technology and partnership from countries which already have commercial experience in uranium enrichment. This was expressed as government policy in January 1979.

Accordingly, proposals were invited from a number of countries to participate in detailed studies of the construction of an enrichment plant in Australia based on their technology. These countries were the USA, France, Japan and the Tripartite organization made up of the UK, FRG and the Netherlands.

In addition, the Government encouraged the setting up of the Uranium Enrichment Group of Australia (UEGA) by the Broken Hill Proprietary Co. Ltd. (BHP), Western Mining Corporation Ltd. (WMC), Colonial Sugar Refining Ltd. (CSR) and Peko-Wallsend Operations Ltd. to study the commercial feasibility of enrichment in Australia. This group has carried out a 14-month pre-feasibility study and submitted its report to the Government at the end of April 1981. During this period the AAEC has acted as technical adviser to the UEGA and to the Government. The report is being studied by the Government and no announcement has yet been made.

The report is expected to answer some basic questions such as:

- Is there a need for additional enrichment capacity in the world and when is a market available?

- Would an enrichment plant be technically and economically feasible in Australia?
- Would Australian industry be interested in investing in such a project and if the answer is yes, how would the project be progressed?

I anticipate that if the answers to these questions are encouraging, the companies will propose a major feasibility study to define the details of a project more closely with one or more owners of technology, potential customers and potential investors. I hope that they do because I am convinced that there is a good case for the enrichment of uranium in Australia and that this would be to the benefit of all Australians.

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