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ADVANCED URANIUM ENRICHMENT TECHNOLOGIES

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HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-SIXTH CONGRESS

FIRST SESSION

SEPTEMBER 22, 1979

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CONTENTS

WITNESSES

	Page
September 22, 1979:	
Dr. Stanley I. Weiss, Deputy Assistant Secretary, Utility and Industrial Energy Applications, U.S. Department of Energy	30
William R. Voigt, Jr., Director, Office of Uranium Resources and Enrichment, U.S. Department of Energy	30
Dr. J. Robert Merriman, Director, Enrichment Technology Division, Union Carbide Corp., Nuclear Division, Oak Ridge, Tenn	129
Paul R. Vanstrum, Vice President, Engineering and Development, Union Carbide Corp., Nuclear Division, Oak Ridge, Tenn	188

APPENDIX

Additional statements for the record 201

ADVANCED URANIUM ENRICHMENT TECHNOLOGIES

SATURDAY, SEPTEMBER 22, 1979

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION,
Oak Ridge Tenn.

The subcommittee met, pursuant to notice, at 9:10 a.m., in the auditorium, American Museum of Science and Energy, Hon. Michael McCormack, presiding.

Mr. MCCORMACK. The meeting will please come to order.

Good morning, ladies and gentlemen. Today, the Subcommittee on Energy Research and Production of the Committee on Science and Technology of the House of Representatives will conduct an oversight hearing on the subject of advanced uranium enrichment technologies.

I'm Congressman Mike McCormack, chairman of the subcommittee, and the other subcommittee members who are present here today are Mrs. Marilyn Lloyd Bouquard—of course, I'm sure you know Marilyn and are all very proud of her as your own Representative. She is, as you know, one of the active members of the subcommittee. On my left is Congressman Toby Roth of Wisconsin and on Mrs Bouquard's right is Congressman Ronnie Flippo of your neighboring State of Alabama. Both these gentlemen are also members of the subcommittee. Over on the left end of the table is Congressman John Duncan of Tennessee, who is not a member of the committee, but we're making him an honorary member of the committee today because he's been so kind as to join us in coming into his home State.

We couldn't have picked a better place to hold hearings on uranium enrichment. We're happy to be here and happy to see a little bit of sunshine breaking through this morning and I tell you I have faith in your people telling me we're going to have sunshine today because I brought my sunglasses along. We're happy to be here, happy to be back in Oak Ridge to visit again, and we appreciate the wonderful hospitality we've already experienced. Coming back each time, we see and learn many new things, and renew many old friendships, and it's a very pleasant experience.

In addition to that, there's no question that Oak Ridge is clearly the center of the uranium enrichment universe. We can say that Oak Ridge is where uranium enrichment had its birth and certainly where the center of uranium enrichment for nuclear power production exists. The fact that it is both the center for prodution of enriched uranium for the development of new enrichment technologies is certainly a credit to all of you who have done so much to make Oak Ridge the splendid research and development and production center that it is.

The hearing today we'll hold has several purposes. First of all, we want to learn about projected requirements for enriched uranium. This is critically important because we must be about the business of funding the facilities in a timely manner. We must assess the status of the gas centrifuge work both here at Oak Ridge and at Portsmouth, Ohio, and review the state of the art with respect to other advanced enrichment technologies, especially laser isotope separation, to discuss the issues and concerns of the country dealing with advanced enrichment technologies when they are implemented.

The incentives, of course, are very important. First of all, we save a huge amount of electricity by switching from a diffusion process to gas centrifuge. This is a most important thing, and one can make the argument I believe that we should just go ahead and start converting. We need to understand as much as we can about this particular subject. The second is, of course, that with advanced enrichment technologies, especially laser isotope technology, we can look seriously at the business of stripping additional uranium 235 from the large amount of uranium tails stored here. With such technology the depleted uranium itself becomes a most significant source of fuel and of energy equivalent to many billions of barrels of oil and probably equivalent to more than all of the other energy sources we have in this country today. So it's critically important. I suppose it's important to those of you here in Tennessee too.

One of the debates we have been having with respect to the breeder program is how much we have. I keep trying to explain to my friends from Harvard, who keep telling us we have an unlimited supply of fuel but not enough money, that the limitation is not money at all. Nobody is going to grind up the State of Tennessee just to get those traces of uranium out of Tennessee shales at any price at all. The limitations are not financial, they are environmental, and this is one of the reasons, of course, that we have been pushing so hard for the breeder program and one of the reasons we have been pushing so hard for the Clinch River breeder project. All of us here at the table have worked very hard on that project to make it safe. We thought we might be able, this morning, to tell you that the House has appropriated money for fiscal year 1980 for the Clinch River breeder project. Unfortunately, something happened along the way to passing that legislation. Somebody stuck a congressional pay raise on the same bill, and as a result, it has been involved in some—it has disintegrated into the world of propaganda, I should say, and political rhetoric and we'll have it before us again next week. Unfortunately, there is a rule where any amendment on any aspect of the legislation can be amended or debated almost endlessly. So we don't know exactly what will happen, but we can assure you that we will be working with the Appropriations Committee, all of us together, to be certain that this program is funded. But it really is not directed to the amount of uranium that's available and to the amount of enrichment capacity available and to the enrichment technologies. They all tie together.

I should say that the committee is deeply concerned with this business of enrichment technologies themselves and the budgetary considerations. We'll be looking at the 1981 budget soon and we will be looking at—we are trying to get a realistic grasp on exactly what

must be done so the committee can take an even stronger leadership role in helping determine policy for this country in these areas.

Today, we have several witnesses who will be addressing us; Dr. Stanley Weiss who is Deputy Assistant Secretary of the Department of Energy's Utility and Industrial Energy Applications and he will discuss, among other topics, the administration's present policy on uranium enrichment as incorporated in DOE's program. He will be joined at the table by Mr. William Voigt, who is Director of the Office of Uranium Enrichment of the Department of Energy and has directed both the gaseous diffusion and centrifuge development programs for some time. Following Mr. Voigt will be Dr. J. Robert Merriman, director of the Enrichment Technology Division of Union Carbide here at Oak Ridge and finally we will hear from Dr. Paul Vanstrum, Vice President of Engineering and Development for Union Carbide, who has been tracking these technologies for a considerable period of time.

Before we receive our testimony, however, we would like to ask the members of the committee who are here if they would like to make some opening comments. I'd like to call on your own Representative in Congress, Marilyn Lloyd Bouquard, if she would like to make a few statements.

Mrs. BOUQUARD. Thank you, Mr. Chairman, I would like to take this opportunity to welcome you to Oak Ridge. I think this is the first hearing that we have had in the community since jurisdiction over the nuclear programs in general and enrichment in particular was transferred to our committee from the Joint Committee on Atomic Energy. I want you to know how much I appreciate your willingness to give up your weekend in particular for these hearings and briefings and tours this afternoon. I think we have one of the most beautiful and dynamic areas of our Nation and if the weather prevents you from enjoying the scenery, I'm sure you will enjoy our southern hospitality and enjoyed our delicious country ham this morning as an example. I hope your time here will be most informative and enjoyable, and for those of you who are here, I think we should realize for a Member of Congress to give up their precious weekend away from their family to go to another district in the interest of our country certainly shows their dedication to performance.

Mr. Chairman, I'd like to make one or two observations before we begin. As members of the subcommittee, you are no doubt aware that we have some considerable confusion and substantive differences with the Department of Energy on the subject of uranium enrichment in this year's authorization bill. This is a situation that I think need not exist and I hope it is one that can be eliminated fully by the time next year's budget request is sent to Congress.

I am personally greatly concerned about what I perceive as the failure of the Department to maintain the pace of the centrifuge project. I have serious doubt as to how much of the nuclear generating capacity utilized by the Department reflects a prudent planning base for enrichment demand by the year 2000. I am not satisfied with DOE's estimates of the source of supply, that they represent accurate assessments of nuclear resources, particularly in light of our stated national objectives of becoming a reliable source of enrichment services to the international community.

As a final comment, though I have a number of questions that we will discuss at the appropriate time, I was disappointed that the Department in its centrifuge program eliminated one of the two qualified and experienced centrifuge component manufacturers. It would appear to me that the Department's objective of encouraging competitive, qualified deals with manufacturing companies would have best been served by expanding the present base of three to include four.

And with these comments in mind, Mr. Chairman, I am delighted to have with us the Department's able spokesmen and I am confident we are going to make substantial progress toward eliminating some of my concerns.

Thank you very much.

Mr. McCORMACK. Thank you, Mrs. Bouquard.

I should also mention that we have several staff members whom I would like to introduce. Before I ask the other members, let me introduce them.

On my immediate right is Dr. Steve Lanes who is the staff director for the subcommittee. The second man on my left is Dr. Robert Leachman, minority staff man for the committee. You were here at Oak Ridge, weren't you, Robert?

Dr. LEACHMAN. I was in Los Alamos.

Mr. McCORMACK. OK, he was primarily from Los Alamos. Directly behind me is Dr. Allan Mense, who many of you know, who was part of the fusion program here at Oak Ridge and who we have stolen from you and now have in Washington, D.C., and behind me on my left is a new minority member of the staff, Mike Helmantoler, and I want you all to know who they are.

Now I would like to ask Congressman Roth if he would like to make any opening comments.

Mr. ROTH. Thank you, Mr. Chairman. Because our time is at such a premium, I will forgo our prepared text, but I would like to insert this into the record.

Mr. McCORMACK. Without objection, it will be inserted in the record at this point.

[Prepared statement of Hon. Toby Roth, Subcommittee on Energy Research and Production, follows:]

PREPARED STATEMENT OF HON. TOBY ROTH, SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

Thank you, Mr. Chairman. It is indeed a pleasure to be here at Oak Ridge for the purpose of these important hearings.

It is appropriate that Oak Ridge should be chosen for this hearing on uranium enrichment because of its historical significance as the site of the first activity during World War II. It is also extremely useful for us to have field hearings such as this so as to become better informed and to give informed citizens the opportunity to be involved in the congressional process rather than restricting such participation to activities in Washington, D.C.

We are appreciative of the hospitality of the Oak Ridge project in providing us with a tour of facilities this afternoon. We will be particularly interested in the progress in enrichment, which is a national issue and will be discussed this morning. I also am interested in the exciting advances made toward the possibility of fusion energy here at Oak Ridge. Fusion research is an important activity in my home State of Wisconsin with three good-sized groups involved in research at the University of Wisconsin.

It is important that Congress take real interest in the nation's enrichment capacity. This is a subject that has important ramifications for the United States'

ability to improve its energy future, Also, our enrichment capacity is important in helping to supply the rest of the world with nuclear energy and in the context of continuing concerns about the proliferation potential of such technology.

Enrichment involves large dollar expenditures, and so it is appropriate the Congress have first-hand knowledge of how these expenditures are made so we can evaluate the budget constructively. The funding amounts are generally of the order of $1 billion. For example, the operating expenses for diffusion enrichment each year are over $1 billion, which is recovered by a similar cost for this service. In addition, the United States has just undertaken expansion in its capacity for enrichment by diffusion amounting to over $1 billion. Now we are considering an expansion of enrichment capacity by means of centrifuge enrichment with an ultimate cost of over $5 billion at the Portsmouth, Ohio plant.

For the United States to responsibly plan for the energy future, these investments and expenditures are most necessary. It is important for all of us, the Congress and the executive alike, in Washington and the field, to assure that these plans and expenditures make sense.

Thank you, Mr. Chairman.

Mr. ROTH. I would like to thank Mr. Leachman for helping with these prepared remarks.

I would like to make a personal observation, Mr. Chairman, however.

First of all, since arriving here in Tennessee, I have had the pleasure of meeting some of the most cordial, intelligent, and dedicated people I have met anywhere. It's people like the people we have here that make our Nation the great Nation that it is. I wish we had a week to spend in this area to study and analyze the fabulous work being done here, but unfortunately because of time limitations, we do not have that luxury.

Mr. Chairman, I believe that these people realize the work that you are doing, and appreciate it, and I also realize that their work is acknowledged by members like you and other members of this committee on the floor of Congress and I am sure that you will carry the message back of their dedication to Capitol Hill.

Mr. MCCORMACK. Thank you very much, Mr. Roth.

Mr. Flippo, would you like to make any comments?

Mr. FLIPPO. It's obvious to me—I am delighted that the gentleman from Wisconsin, Mr. Roth, enjoys the area so much—it's obvious to me after his remarks that he will likely be invited back again.

I want to associate myself with his remarks and tell you that it is a great pleasure for me to be here in your beautiful community, to be in the district of my friend and colleague, Marilyn Lloyd Bouquard, as well as John Duncan. It is a pleasure to be with a gentleman who has rendered so much service on the Ways and Means Committee and I am sure you already know that probably the staunchest advocate for this industry in the U.S. Congress, in my opinion, is the chairman of this committee, and it is a pleasure to serve with him and follow his excellent leadership as we try to find some way to advance the programs that we have here to meet the needs of the Nation.

I just want to tell you that I am very hopeful of the success of the great University of Tennessee today, but I will not agree with that when the University of Alabama and Tennessee meet later in the season. It is great to be in Big Orange Country, and thank you very much.

Mr. MCCORMACK. Thank you. OK. Mr. Duncan, would you like to make any comments?

Mr. DUNCAN. Very briefly. I want to thank you for making me an honorary member of the committee. I'm not sure what obligation it entails but I will accept it.

I do want to welcome my colleagues to Tennessee and I'll reiterate what Ronnie Flippo said, that Mike, you have been a great friend of Oak Ridge since you have been in Congress and you are almost the foremost friend we've got in Congress and we appreciate all you've done and I know Congressman Roth addes much to it and also our friend from Alabama, Congressman Flippo, he is also a good friend of this area and we all work together.

Thank you very much for coming.

Mr. McCormack. Thank you. It is a pleasure to work with you and I must say that my support of the projects at Oak Ridge have been because I think it is important to the country.

I should not let the opportunity go to congratulate you and Marilyn, especially Marilyn, for the tremendous work you have done in getting support for Oak Ridge and for Anderson and Roane Counties—Roane, is that right?—I've got them memorized now as many times as Marilyn talks about them—and the great job she has done in that respect.

I must advise everybody that we are going to have to hold to a very tight schedule today. Normally, this committee operates in a rather informal manner but we are going to be a little tight because we must adjourn by 11:30. That means that we must finish with our present witnesses by 10 a.m., which is 36 minutes from now, and finish Dr. Merriman at 10:45 and the final witness, Mr. Vanstrum, at 11:30. We must hold that schedule and the chairman will take what ever steps are necessary to do so.

Gentlemen, we have here Dr. Weiss and Mr. Voigt before us. We have your testimony before us and it will be received without objection and inserted in the record at this point, and you may proceed as you wish.

[The prepared statements of Mr. Weiss and Mr. Voigt follow:]

Statement of
Stanley I. Weiss
Deputy Assistant Secretary
For Utility and Industrial Energy Applications
U. S. Department of Energy
Before the Committee on Science and Technology
Subcommittee on Energy Research and Production
U. S. House of Representatives
September 22, 1979
at
Oak Ridge, Tennessee

INTRODUCTION

Mr. Chairman and members of the Committee, I welcome the opportunity to discuss with you today the Department of Energy's Uranium Enrichment Activities Program. Though there are differences of emphasis being being placed on the nuclear option, we continue to find it an option of major importance.

The success of a particular energy system depends to a great extent on the availability of its fuel supply. That availability is governed not only by natural resources, but by the institutional and capital decisions that must be made to build the physical plants that will convert these natural resources into viable and economical energy supplies. For most nuclear power systems that means at a minimum the viable supply of uranium ore and enrichment services.

The Department of Energy's role in the fuel cycle, intrinsic to nuclear power electricity generation, is the provision of enrichment services which upgrade the concentration of Uranium-235 to a level sufficient for U.S. reactor fuels. This Government activity is a major business enterprise whose administration has become increasingly difficult as the demand for U.S. enrichment services has, at least for the time being, been severely decreased. Our programmatic management seeks to recognize these changes, remain flexible to cope with additional variations, and maintain the U.S. as an assured cost-competitive supplier for domestic and free world customers. By necessity this planning must be a continuing process.

Uranium Enrichment is a singular enterprise. It involves large corporations, Government involvement, and national policy. Its business level is measured in billions of dollars. The worldwide growth of nuclear power has to date, been facilitated by existing enrichment facilities, principally U.S. The U.S. is no longer the only supplier that provides these services. EURODIF, URENCO, and Techsnabexport also perform this function.

The decrease in the demand for enrichment services, noted earlier, has created a highly competitive marketing environment. However, we believe that our new Adjustable Fixed-Commitment contract, customer-oriented marketing effort, highly reliable existing production facilities, and a more economical gas centrifuge enrichment process coming on-line in the next decade at Portsmouth, Ohio, should retain DOE in a competitive position.

We are taking steps to implement the President's commitment to provide adequate and timely supply of nuclear fuel for domestic and foreign needs in a manner that keeps our customer's enrichment requirements in mind and will assure meeting the demands of the U.S. and world nuclear power market in a cost effective manner.

Mr. William Voigt, Director of the Department's Uranium Enrichment and Resource Evaluation activities, will describe for you today our projections of nuclear power growth, the factors that we have considered in developing our operating plan, the fiscal year 1980 uranium enrichment operating plan, the implications of this operating plan on the gaseous diffusion capacity expansion program, and the gas centrifuge development and construction program. Mr. Voigt and I will be further pleased to answer your questions.

Statement of
William R. Voigt, Jr.
Director, Office of Uranium Resources and Enrichment
U. S. Department of Energy
Before the Committee on Science and Technology
Subcommittee on Energy Research and Production
U. S. House of Representatives
September 22, 1979
at
Oak Ridge, Tennessee

INTRODUCTION

Mr. Chairman and members of the Committee: I am pleased to have the opportunity to appear before this Committee today to discuss the Department of Energy's Uranium Enrichment Program.

URANIUM ENRICHMENT ACTIVITIES

Before discussing the detail of our uranium enrichment activities program, I would like to describe some fundamental concepts for the benefit of those not as familiar with uranium enrichment technology as you, Mr. Chairman.

Uranium, as it occurs in nature, has three isotopes, that is, forms of uranium chemically the same but different in atomic weight and in physical properties. Only about 0.7 percent of natural uranium is uranium-235 (U-235). Since U-235 is fissionable, it is useful as nuclear reactor fuel. The remainder of natural uranium, uranium-238 (U-238), is nonfissionable. Light water reactors for nuclear power generation require U-235 concentrations of about 3 percent.

The original Oak Ridge gaseous diffusion plant began operating under the Manhattan District in 1945 as part of the World War II effort to develop and make nuclear weapons. The Atomic Energy Commission (AEC) later took over Oak Ridge and, as part of an effort to increase weapons production, built the Paducah and Portsmouth plants, which began full production in 1954 and 1956, respectively. These plants, which were built to satisfy defense requirements for highly enriched uranium, now are used primarily to provide enrichment services to domestic and non-U.S. electric utilities. The DOE enriches U.S. and non-U.S. customer's supplied uranium to the desired U-235 product assay in its gaseous diffusion plants at Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky.

Chart 1 depicts the separation of the two principal isotopes, U-235 and U-238 by the gaseous diffusion process. When uranium hexafluoride gas (UF_6) is subjected to a given temperature and pressure, the molecules of the lighter gas (U-235) move, on the average, faster than those of the heavier gas (U-238). Thus, the U-235 molecules will pass through a uniquely porous barrier more often than the heavier U-238 molecules. With each pass across the barrier, the UF_6 becomes very slightly richer in the U-235 isotope. To obtain the enrichment useful for use in nuclear power reactors, about 1200 of these passes are required. Each pass is customarily called a stage (see Chart 2) and the total stages connected in a series are referred to as a cascade.

DOE's three gaseous diffusion plants operate as an integrated complex in order to provide the best use of these facilities. The Paducah plant serves as the bottom stages for both the Oak Ridge and Portsmouth plants. Most of the enriched product from the Paducah plant, which contains less U-235 than required for most power reactor fuels, is shipped to Oak Ridge and Portsmouth for further enrichment.

Another technique for enriching uranium utilizes gas centrifuge technology. The principles of a gas centrifuge process are illustrated in Chart 3. A centrifuge is a cylinder which rotates at a high speed in order to separate two components by centrifugal force. The degree of enrichment in a single centrifuge depends on the mass difference of the isotopes being separated, the length of the rotor, and most importantly the speed of rotation. In large, high-speed centrifuges, it is possible to obtain an enrichment factor greater than that of a gaseous diffusion stage. Gaseous UF_6 is fed into a rotor which spins at high speed inside an evacuated casing. The gas accelerates to approximately the speed of the rotor. Centrifugal force causes the heavier U-238 molecules to move closer to the wall of the rotor, producing partial separation of the U-235 and U-238 isotopes.

An axial countercurrent flow of gas within the centrifuge increases the separation. Feed is introduced near the middle of the rotor, and enriched and depleted streams are removed near the ends. Since the desired enrichment is not obtained in a single centrifuge, a number of machines must be connected in a series known as a cascade. With the proper selection of centrifuges in cascade, the desired percentage of enrichment can be obtained.

DOE has developed the gas centrifuge process to a level of high cost effectiveness and reliability and will construct a gas centrifuge production plant near Portsmouth, Ohio, adjacent to the existing gaseous diffusion facility. I will say more about this subject later in my testimony.

OPERATIONAL PLANNING FOR DOE ENRICHMENT COMPLEX

DOE Projection of Nuclear Power Growth

During testimony presented to this Subcommittee on February 21, 1979, by Dr. Stanley Weiss, our estimate was presented for domestic and non-U.S. nuclear power on-line in 1985 which would obtain enrichment services from DOE. Our estimate, shown on Chart 4, was based on a reactor-by-reactor evaluation of the annual demand for enrichment services. At that time we had forecasted that 115 GWe of domestic nuclear power capacity and 65 GWe of non-U.S. nuclear power capacity, scheduled to be on-line in 1985 which would be supported by DOE enrichment capacity.

The domestic estimates for 1990 included planned reactors which were not then under construction, but which DOE judged would be needed and could be available to meet forecasted electrical power requirements. The non-U.S. projection for 1990 was based on similar consideration, but included only those reactors expected to be supplied under DOE enrichment services contracts. The results of the projection indicated that 185 GWe of domestic nuclear power and 100 GWe of DOE supplied non-U.S. nuclear power would be on line by the end of 1990.

In February, these estimates of DOE supplied enrichment services in 1985 and 1990 were considered reasonable and conservative for planning purposes. Accordingly, our planning for enrichment services has been based on optimizing the DOE enrichment complex operating variables for supplying the needs of 180 GWe in 1985 and 285 GWe in 1990.

After 1990, the growth of nuclear power in the U.S. is less certain. The Energy Information Administration forecasted in April 1979 that by the end of the year 1995, the nuclear power capacity in the U.S. could range from 186 to 224 GWe. The maximum sustaining capability of the DOE enrichment capacity currently authorized by Congress at 0.25% U-235 tails assay is 325 GWe. As we testified in February, the operating plan assumed that 120 GWe of non-U.S. enrichment demand could be supplied by DOE, the remaining 205 GWe of nuclear power which can be sustained by currently authorized capacity could be derived from domestic customers. If this level of nuclear growth is achieved, the entire capacity from the three fully uprated and improved gaseous diffusion plants and the 8.8 million separative work unit (SWU) GCEP plant will be fully utilized by about the mid 1990's.

Since testimony before this Subcommittee on February 21, 1979, several events have occurred which could have important implications with respect to the future of nuclear power in the U.S.

- o The Three Mile Island incident and the resultant uncertainty this incident placed on the future role of nuclear power.
- o The creation of a Presidential Commission to review the safety of nuclear reactors and the future status of nuclear power in the U.S.
- o For the 52 week period ending August 4, 1979, the Edison Electric Institute reported a 5.1% increase in electrical energy distribution in the U.S. A comparable number for the period ending September 2, 1978, was 2.4% increase.

The first two events, as well as others, have had an effect on the growth rate of nuclear power in other countries. The Nuclear Non-Proliferation Act and concerns over U.S. policies regarding reprocessing and breeder reactor deployment have created an atmosphere of uncertainty relative to the U.S. as an assured supplier of enrichment services. The last item indicates that demand for electrical energy may increase at a rate higher than recent experience. The effect this potential increased demand for electrical energy could have on nuclear power in the U.S. is uncertain.

As uncertain as the future normally is for forecasters, these events have created a future that is extremely difficulty to forecast. Nonetheless, we must attempt to develop as reliable a demand forecast as possible in order that we may develop a production plan that will optimize the enrichment complex operating variables. We are now in the process of evaluating the likely effect of these events on future enrichment demand and developing alternate operating strategies to meet varying demand scenarios.

We are also in the final phase of converting the Long-Term Fixed Commitment (LTFC) contracts to Adjustable Fixed Commitment (AFC) contracts, with all AFC contracts to be signed by September 30, 1979. The AFC contract allows our enrichment customers considerably greater flexibility to adjust delivery quantities and to reschedule deliveries. About 95% of our LTFC customers are converting to the AFC contract. As of September 30, 1979, customers who have converted to the AFC contract will be reasonably committed to a firm

delivery schedule for a five-year period which will provide DOE with a much clearer picture of true demand. AFC contracts will comprise about two-thirds of our existing contracts. The remaining one-third of existing contracts are Requirements contracts. These contracts stipulate that enrichment services will be supplied based on the actual requirements of a reactor with only a 180-day notice period required before delivery. The increased flexibility of the AFC contract in addition to the almost unlimited flexibility of the Requirements contract will result in enrichment contractual commitments which we believe will be reasonably in tune to the actual needs of our customers.

Enrichment Services Supply and Demand

The projection of enrichment services demand based on the reactor-by-reactor nuclear power forecast shown on Chart 4 was determined by using standard reactor schedules for a reactor mix consisting of one-third boiling water rector and two-thirds pressurized water reactors with a lifetime average plant capacity factor of about 70%. In addition to these civilian nuclear power reactor requirements, U.S. Government and miscellanesous requirements are also provided for through the planning period. Government requirements are projected to average about 1.0 million SWU's per year. Government users include the Naval Reactor Program, the nuclear research and development programs, as well as, the DOE production reactors. We have also included in our plan miscellaneous requirements such as those needed under short-term fixed-commitment contracts. We project these miscellaneous requirements to average about 0.4 million SWU's per year. The resulting annual demand for DOE enrichment services is shown in Chart 5.

Based on the DOE enrichment services demand projections, we have developed an operating plan for meeting the forecasted requirements. The plan seeks to supply the projected requirements for enrichment services at a transaction tails assay of 0.20% U-235 as long as possible, but at no greater than 0.25%, while maintaining DOE-owned inventories of low enriched uranium at a 14 million SWU minimum stockpile level.

In the spring of 1978 when we found that the near-term projected demand for enrichment services was being delayed, the operating plan had to be revised and construction of the gas centrifuge enrichment plant rescheduled. This action was taken to avoid unnecessarily early inventory buildup and attendant near-term budget expenditures. Accordingly, DOE negotiated with its power suppliers to reduce power in the 1979-1981 period. The resulting enrichment complex operating plan to supply the forecast demand is also shown on Chart 5.

54-835 O - 80 - 2

As is evident from Chart 5, the production of separative work is expected to be less in the next two years than the demand. The difference between these two factors will be made up by drawing down from DOE's current inventory of low enriched uranium. The operating plan for the gaseous diffusion plant production beyond FY 1981 reflects the firm power delivery schedules stipulated in the existing power contracts. These power levels appeared reasonable at the time for use in planning on the basis of both economics and need. Based on these assumptions, enrichment services supply will exceed demand in the period FY 1982 through FY 1985. In the period from FY 1986 through FY 1990, the demand is expected to be greater than the supply and a portion of our customer's requirements will have to come from the DOE's enriched inventory. Beyond 1990, DOE's operating plan assumes that the enrichment complex is operating at a tails assay greater than 0.20% U-235, and contemplates bringing the Portsmouth Gas Centrifuge Enrichment Plant capacity on line in a manner such that supply will equal demand.

We plan to operate the enrichment complex such that the current 0.20% U-235 transaction tails assay will be maintained as long as possible, thereby allowing customers to obtain nuclear fuel close to the minimum projected cost of the fuel. Eventually, with the new contracts DOE expects to sign as a result of the DOE marketing efforts, the transations tails assay may need to be increased to 0.25% U-235. However, we do not expect this to occur until well into the 1990's.

The low enriched uranium inventory levels are shown as a function of time for the current operating plan in Chart 6 which displays the separative work contained in DOE inventory of low enriched uranium. As can be seen, the inventory will decrease slightly over the next 2-year period, then increase through the mid-1980's and then decrease again until a target sustaining inventory level of 14 million SWU of low enriched uranium is achieved in 1990.

Fourteen million SWU is a prudent minimum inventory level and is comprised of:

1. 9 million SUW's as a working inventory (equivalent to three months of production from the DOE enrichment plants, when operating at full capacity after completion of the Gas Centrifuge Enrichment Plant). This inventory will serve as a buffer between the levelized daily production of enriched uranium in the intermediate day-to-day shipments of

finished product to enrichment services customers. This working inventory provides assurance to customers that DOE will deliver on schedule.

2. 5 million SWU's of the inventory are for what President Carter has identified as a possible set aside for international nuclear fuel assurance in response to Section 104(b) of the Nuclear Non-Proliferation Act of 1978.

In summary, near-term DOE enrichment production has been decreased in light of reduced projected demand for enrichment services by avoiding unnecessary early budget expenditures in the gas centrifuge enrichment plant and reducing near-term production of enriched uranium through minimum power levels in the 1979-1981 period.

GASEOUS DIFFUSION OPERATIONS AND EXPANSION

I would like to briefly discuss some of the details of gaseous diffusion plant operations and DOE's capacity expansion program.

Cascade Operations

The electric power for the gaseous diffusion plants is supplied by the Tennessee Valley Authority (TVA), Electric Energy, Inc., (EEI) and the Ohio Valley Electric Corporation (OVEC). TVA supplies all of the power to the Oak Ridge, Tennessee, plant and a portion of the power to the Paducah, Kentucky, plant. The remaining power to the Paducah plant is supplied by EEI. All of the power to the Portsmouth, Ohio, plant is supplied by OVEC. The TVA supplies all of its power through its normal distribution system. Power from EEI and OVEC is supplied by three generating stations dedicated to supplying power to the DOE enrichment plants. EEI, sponsored by four utilities in the Illinois, Missouri and Kentucky areas, owns and operates a generation station in Joppa, Illinois; OVEC, sponsored by fifteen private utilities in the surrounding area, owns and operates two generating stations, the Clifty Creek station near Madison, Indiana and the Kyger Creek station near Gallipolis, Ohio. We currently have long-range contracts with TVA and EEI that will run into the 1990's and are currently negotiating with OVEC to extend that contract into the 1990's as well. These contracts will provide the power needed to operate the plants at their improved and uprated capability, although some of the TVA power will not become available until 1984 and 1985.

As I mentioned earlier, the projected power usage in the gaseous diffusion plants in the next fiscal year will be lower than in past years. Consistent with our long-term production planning, we have reached agreements with each of our power suppliers to keep power purchases in fiscal year 1980 as low as possible without incurring any demand payments for power not taken. The power scheduled

to be delivered in FY 1980, approximately 3,049 megawatt-years (2,856 megawatts years of cascade power), will be sufficient to operate the three gaseous diffusion plants at the lowest practical power level at each plant while still ensuring safe operation of the plants. We would expect to produce about 10.5 million separative work units at this power level. We now estimate that our FY 1980 costs for power to the diffusion plants will be around $613 million. This is about $65 million over the amount Congress has appropriated in our FY 1980 budget and reflects our latest estimate of power to be delivered to the diffusion complex and unit cost projections. DOE is now evaluating options to resolve this funding deficit in FY 1980.

Gaseous Diffusion Capacity Expansion Programs

As part of DOE's commitment to have sufficient capacity to serve existing and future uranium enrichment requirements, two major diffusion capacity expansion programs have been underway for several years. These projects are, the Cascade Improvement Program (CIP) and the Cascade Uprating Program (CUP). The technological base for both these programs is centered around a group of advanced diffusion stage components and high quality barrier material which have been tested as full-scale prototypes in the production plants.

The CIP program, when completed, will increase the capacity of the existing diffusion plants by about one-third or about 5.5 million separative work units (SWU's) per year. The program, which started in 1971, is essentially on schedule and within the cost estimate. As shown in Chart 7, at the end of the third quarter of this fiscal year, 2,263 stages had been modified and equipped with new barrier. By the end of this year, we expect that the program will be over 75% completed. The original planning for the program is based on installing new barrier in a total of 3,167 plant stages with a targeted completion date being the end of FY 1981. Due to a prolonged work stoppage at the Portsmouth plant, which began in early May of this year and is still in progress, the scheduled September 1981 completion date will not be met at that site. The other two sites are expected to complete the CIP program on schedule.

The Cascade Uprating Program implements the second segment of our planning for expanded gaseous diffusion plant separative capacity at the three plant sites. CUP will increase the capacity of the improved plants by an additional 20 percent or about 4.6 million SWU's per year by uprating the equipment to allow the plants to use electrical power more effectively. This is achieved by increasing the power capability of the process equipment from 6,065 to a new rated capacity of 7,380 megawatts. However, for planning purposes we are assuming that power utilization by the three plant diffusion

complex will not exceed 7060 megawatts as purchase of the last increment of CUP power at Portsmouth (320 MW) does not appear economical at this time. Of course, we always have the option to contract for this power if the economic picture changes or circumstances develop requiring this capacity. CUP is being accomplished concurrently with CIP. As shown on Chart 8, CUP, which started in 1974, is on schedule with 2585 stages uprated as of the end of the third quarter of FY 1979. The program schedule indicates that over 66% of the program (2742 out of a total of 4140 stages to be uprated) should be completed by the end of FY 1979. However, as is the case with CIP, the prolonged work stoppage at Portsmouth is expected to impact on the schedule. When CIP and CUP are completed, the total rated capacity of the enriched uranium diffusion complex will be 27.3 million SWU's per year.

GAS CENTRIFUGE DEVELOPMENT AND CONSTRUCTION

I now would like to turn to our efforts on gas centrifuge development and construction. As you know, the Gas Centrifuge Enrichment Plant (GCEP) is under construction at Portsmouth, Ohio, and the development program is completely oriented toward final development and demonstration of a centrifuge production model for installation in GCEP. The centrifuge program has been around since 1960, and our contractors and field managers have made truly outstanding breakthroughs during 19 years of sustained progress. Today, among the various countries now engaged in centrifuge development, our program is second to none. I am delighted that you could come to Oak Ridge today to see for yourself just where we are in centrifuge development.

We have selected a centrifuge design for GCEP and are now in the final stages of demonstration and qualification prior to production. Our centrifuge is really an impressive piece of equipment which we believe to be considerably more technologically sophisticated than our European competitors. This size centrifuge was selected in early 1977, and for the last two and a half years has undergone exhaustive top to bottom testing. Minor design changes are still being tested to confirm improvements to this centrifuge. Prototype models of the GCEP design are currently in various stages of development, testing, and qualification for GCEP, and we are certainly drawing on our previous 19 years experience in the program.

As in any development program where aggressive plans are being pursued to glean more of the ultimate potential of the process, there will be occasional setbacks in the program. Just last year, several GCEP prototype centrifuges operating in the reliability test facility here in Oak Ridge failed and had to be repaired. A team of outside consultants was called in, and they confirmed our own diagnosis and

analysis. Changes have been made, and the centrifuges are again being installed for operation to provide final proof that we do have a quality centrifuge.

To sum up, we are confident that centrifuge technology will be ready for large scale application in GCEP, and we are pursuing an aggressive development program to ensure this goal. In some cases, more than one design choice for a particular component is still being studied to establish if one has any outstanding benefits over the alternate designs. In other cases, a backup design is still being studied just in case the selected component develops a problem later on. And in still other cases, alternate designs are being studied to make possible more efficient, more productive or more reliable centrifuges for later use.

In addition to the development of the initial GCEP centrifuge, we are also developing an improved centrifuge that we could use in some of the later last GCEP buildings, as well as to replace any GCEP centrifuge which reaches the end of its expected life. We expect that by the mid-1980's we could have developed an improved centrifuge ready for final qualification. We foresee that this improved centrifuge could give us as much as a ten percent increase in performance relative to our current centrifuge, and that by the late 1980's, we could achieve up to an additional 20 percent increase in production capacity relative to the current model. We do intend to pursue vigorously the development and qualification of more efficient, more productive, and more reliable centrifuges.

Looking specifically at the Portsmouth plant, the GCEP will ultimately provide approximately 8.8 million SWU's per year of additional uranium enrichment capacity. The FY 1980 budget and operating plan assumes installation of 2.2 million SWU/year capacity by 1988. Additional production capacity will be added in 1.1 million SWU/yr increments as demand for enrichment services indicates the need. The plant, being built on DOE property near Piketon, Ohio, adjacent to the existing Portsmouth Gaseous Diffusion Plant (GDP), will operate in an integrated mode with the three existing gaseous diffusion plants.

The commitment by President Carter and his Administration to build the GCEP has allowed DOE to assure existing and new uranium enrichment customers that it expects to provide such services at a transaction tails assay no greater than 0.25 percent U-235, a level that conserves the supply of natural uranium. The Adjustable, Fixed-Commitment (AFC) contract allows the customer to terminate the contract with no penalty if the transaction tails assay exceeds 0.25 percent.

The GCEP facilities will consist of eight centrifuge process buildings with a total floor area of 2.3 million square feet. Other facilities include the Recycle/Assembly Building, and administrative, support, test, and service facilities as required. The electrical power consumption of the GCEP will be only 135 megawatts, about 5 percent of what a gaseous diffusion plant of similar capacity would require.

The GCEP facility design began in March 1978. All the major architect-engineers have been selected and are actively designing the plant. The present schedule calls for the major facility designs to be completed by mid 1982. Chart 9 lists the architect-engineer firms and the status of their respective efforts.

The GCEP project has advanced to the construction stage and the Construction Manager/Constructor (Stone & Webster Engineering Corp.) has been selected to manage the work. Chart 10 depicts the construction and site preparation activities that are underway and their status. An award has been made for the procurement and erection of the structural steel for the first process building. Other major construction actions include the award of long electrical equipment procurements.

The Phase I centrifuge manufacturing contracts (Boeing, Goodyear & Garrett) have been selected and are under letter contracts. As you know, Boeing will break ground here today for their machine manufacturing plant which is expected to employ approximately 200 persons. Negotiations with these firms are proceeding well, such that definitive contracts are likely to be in effect by the end of CY 1979. The first qualification machines are scheduled for delivery to the Centrifuge Plant Demonstration Facility in October of 1980. The first production machines are scheduled for delivery and first article testing in August 1981.

To date, the GCEP project has incurred costs of approximately 180 million dollars and has additional commitments totaling in excess of 300 million dollars.

In summary, I believe the DOE FY 1980 GCEP Authorization and Appropiation requests as submitted to Congress will permit the continued maintenance of the GCEP progress fully in accord with the goals and objectives of all concerned, and that the harmonious efforts of both the Administration and Congress are responsible for the gratifying GCEP progress to date.

Mr. Chairman, this completes my discussion of the Uranium Enrichment Program, I would be happy at this time to answer any questions.

CHART 1

GASEOUS DIFFUSION STAGE

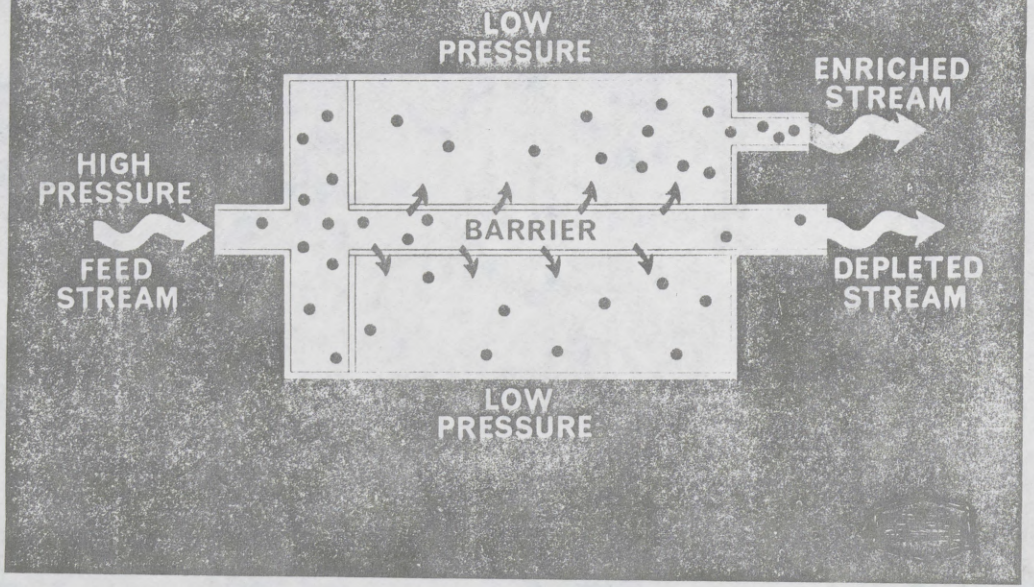


Chart 2

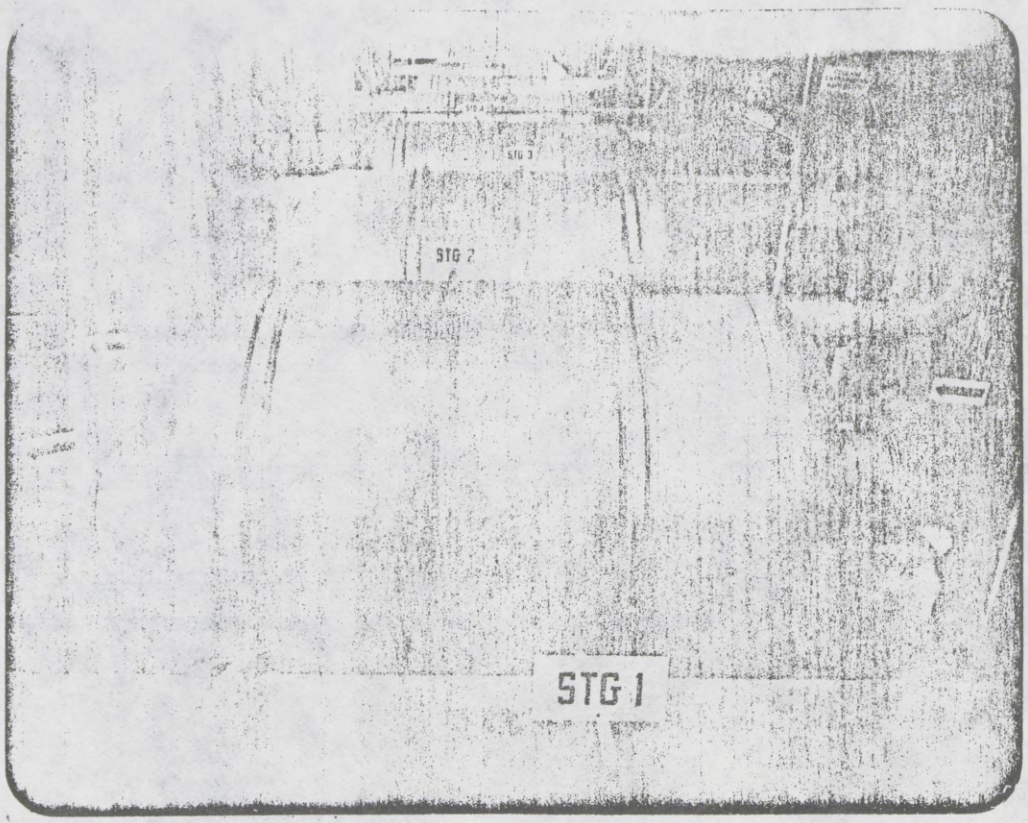
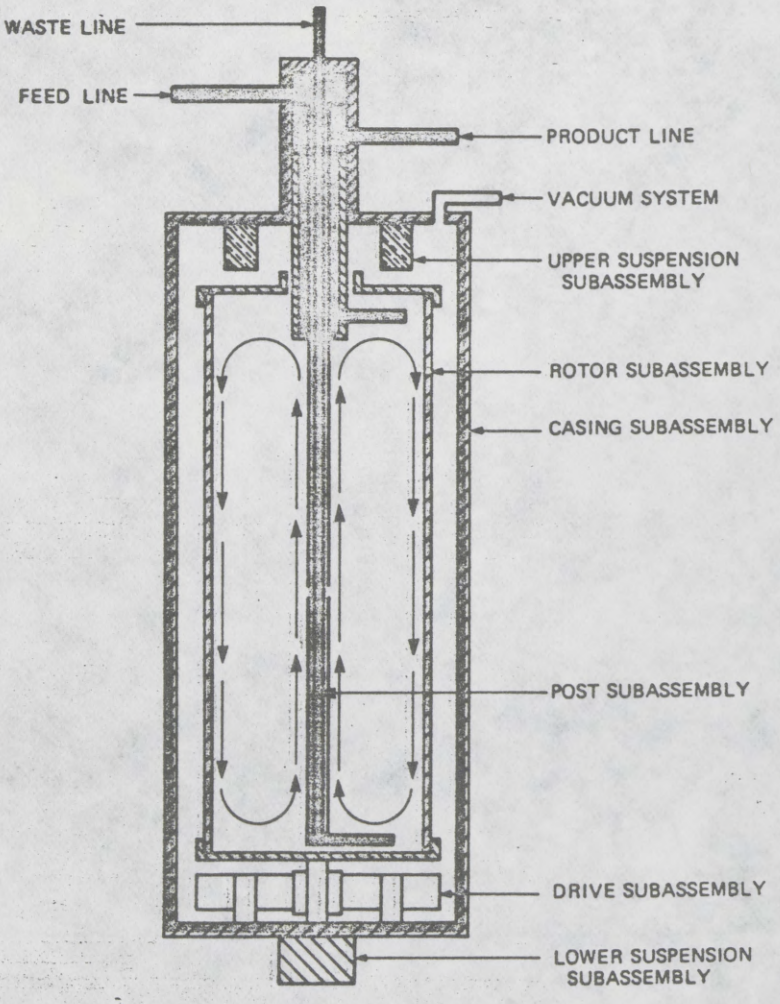


Chart 3



SCHEMATIC OF GAS CENTRIFUGE

Chart 4

DOE PROJECTION OF NUCLEAR POWER REACTORS SERVED BY DOE ENRICHMENT PLANTS

IN GIGAWATTS

	END OF 1985			END OF 1990		
	DOMESTIC	NON-U.S.	TOTAL	DOMESTIC	NON-U.S.	TOTAL
UPPER LIMIT OF REACTORS UNDER CURRENT DOE ENRICHMENT CONTRACTS	115	65	180	175	90	265
POSSIBLE ADDITIONAL REACTORS	0	0	0	5	5	10
MORE SPECULATIVE ADDITIONAL REACTORS	0	0	0	5	5	10
	115	65	180	185	100	285

Chart 5

ANNUAL SEPARATIVE WORK SUPPLY & DEMAND

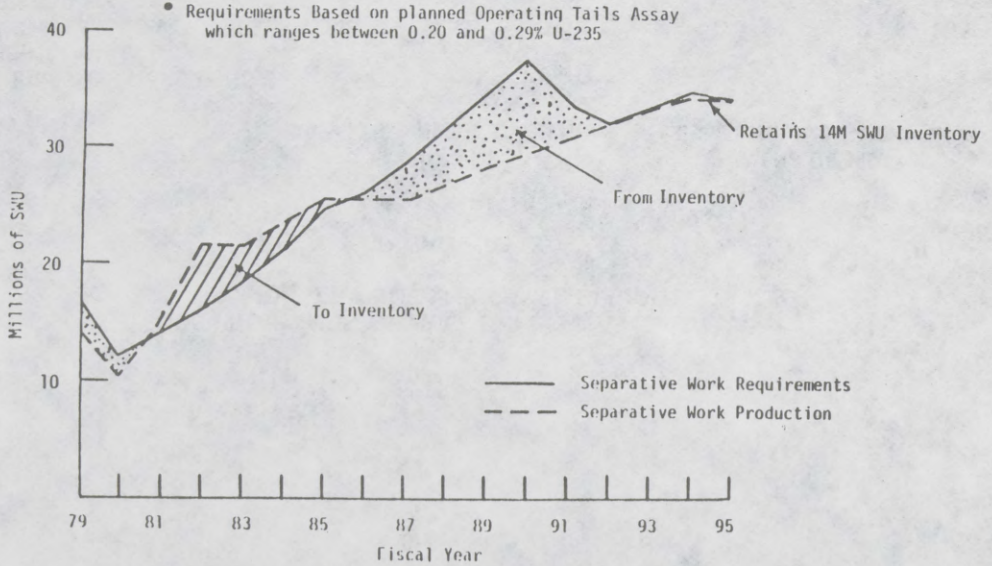


Chart 6

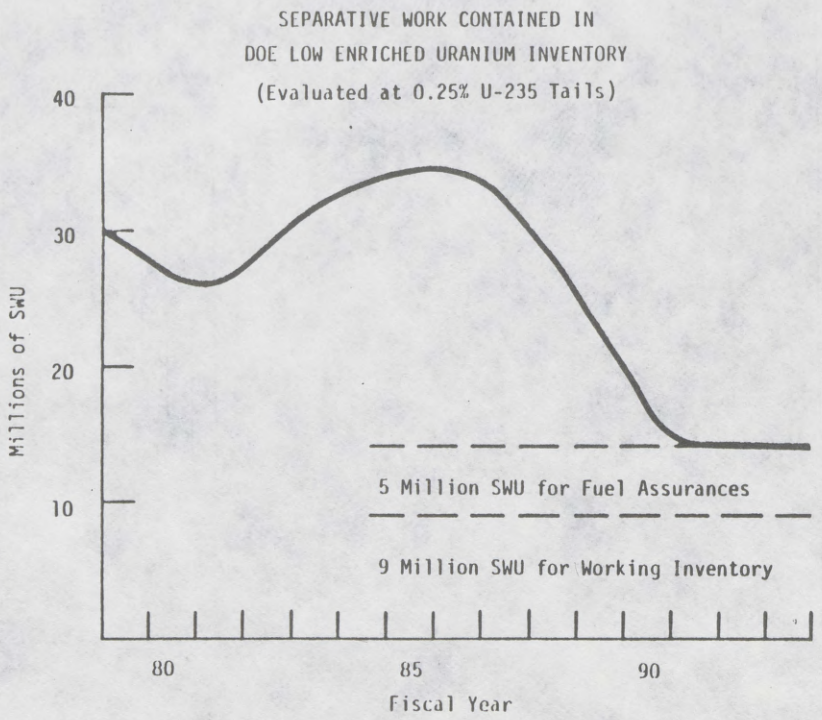

SEPARATIVE WORK CONTAINED IN
DOE LOW ENRICHED URANIUM INVENTORY
(Evaluated at 0.25% U-235 Tails)
40
30
20
10
Millions of SWU
5 Million SWU for Fuel Assurances
9 Million SWU for Working Inventory
80
85
90
Fiscal Year

Chart 7

NEW BARRIER STAGE: JSTALLED BY CIP

Scheduled/Actual

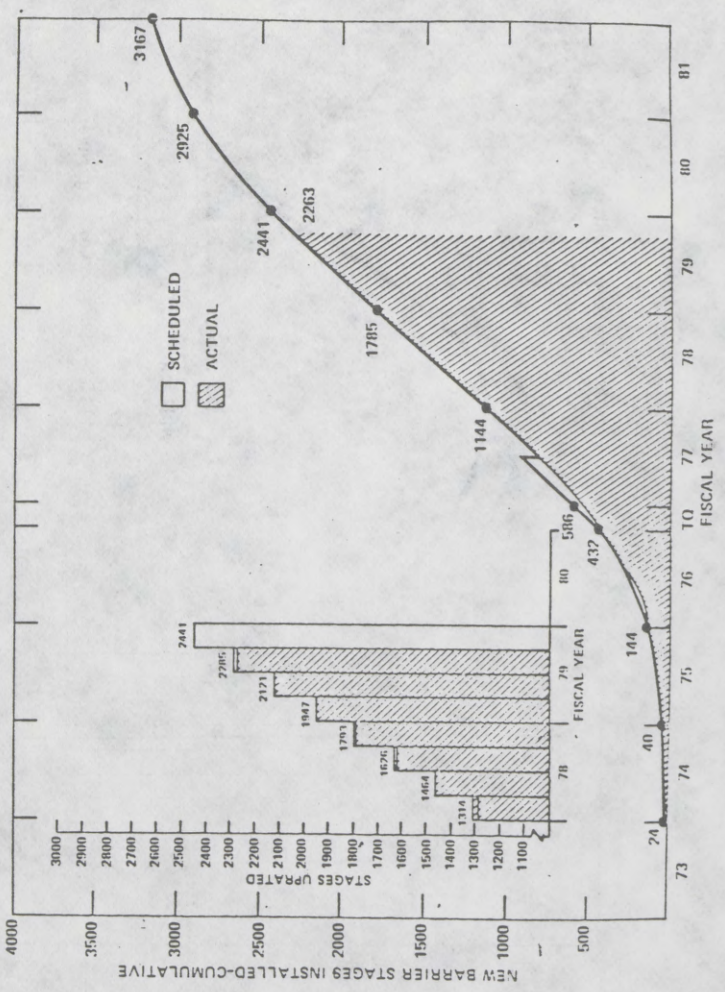


Chart 8

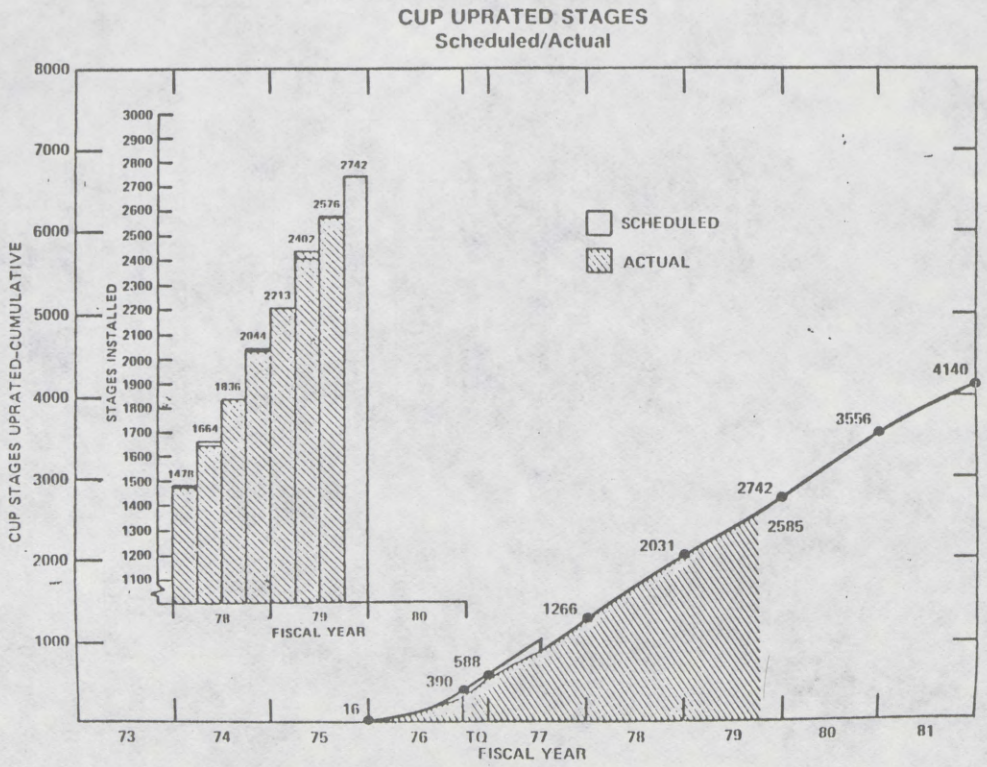

CUP UPRATED STAGES
Scheduled/Actual
CUP STAGES UPRATED-CUMULATIVE
STAGES INSTALLED
FISCAL YEAR
SCHEDULED
ACTUAL
8000
7000
6000
5000
4000
3000
2000
1000
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1478
1664
1836
2044
2213
2407
2576
2742
78
79
80
16
390
588
1266
2031
2585
2742
3556
4140
73
74
75
76
TQ
77
78
79
80
81
FISCAL YEAR

Chart 9

AE FIRMS

NAME	WORK	% COMPLETION (TITLE I & II)
CATALYTIC, INC.	SITE SERVICES	36%
FLUOR ENGINEERS & CONSTRUCTION	PROCESS BUILDINGS	25%
BECHTEL, INC.	R/A BUILDING & EQUIPMENT	25%
COMMONWEALTH ASSOCIATES, INC.	ELECTRIC POWER	67%
KZF, INC.	COMPUTER FACILITY	90%
DALTON, DALTON NEWPORT, INC.	GCEP ADM. BUILDING	100%
HOWARD NEEDLES, TAMMEN & BERGNDOFF	WATER & SEWAGE FACILITIES	99%
POLYTECH, INC.	FIRE STATION	100%
MADISON-MADISON INTERNATIONAL	GUARD STATION	45%
COUCH & ADAMS	ENGINEERING OFFICE BLDG.	100%
McCARTY, BULLOCK, & HOLSAPLE	SEPARATION SYSTEMS	100%
UCC-ND	COMPUTER FACILITY ADDITION	100%
SDC/DMJM	SYSTEMS SUPPORT CONTRACTOR	LEVEL OF EFFORT

54-835 O - 80 - 3

Chart 10

CONSTRUCTION STATUS (8/28/79)

CONTRACT	% COMPLETE AUG	EXPECTED COMPLETION
MOBILE EQUIPMENT GARAGE	94%	SEPTEMBER 1979
GENERAL RECEIVING WAREHOUSE	85%	SEPTEMBER 1979
SOUTH PERIMETER ROAD	70%	SEPTEMBER 1979
RECIRCULATING HEATING WATER SYSTEM	50%	MARCH 1980
ROUGH GRADING	18%	OCTOBER 1980
FIRE STATION	8%	MARCH 1980
TRUCK SCALE & SALT STORAGE BLDG.	75%	SEPTEMBER 1979
RAILROAD, PATROL ROAD & FENCING	30%	JANUARY 1980
WAREHOUSE MODIFICATIONS & STORAGE YARDS	33%	FEBRUARY 1980
WEST PERIMETER ROAD	0%	JUNE 1980

STATEMENT OF DR. STANLEY I. WEISS

Dr. WEISS. Thank you, Mr. Chairman, members of the committee and honorary member.

It is a pleasure to be able to testify in the heartland of our enrichment activities conducted by the Department of Energy and also have you here to, in a sense, kick the tires, but do it very carefully.

The nuclear option is not only an accepted, but a vitally necessary element of the Federal Government's policy for energy, and the maintenance of that option rests very heavily with our ability to supply enrichment services to keep viable both the nuclear powerplants of the United States as well as those in the free world that require those services.

To that end, we believe we have developed an active policy of maintaining adequate supply through the gaseous diffusion enterprise, as well as providing for the economies that will be the benefits of the gas centrifuge developments now under way.

We have certainly been confronted with a changing immediate demand for nuclear power and, therefore, our enrichment services. As a result, we believe we are taking a prudent and flexible approach in proceeding with our enrichment processes, both from the standpoint of power supply and from the standpoint of scheduling the gas centrifuge enrichment plant.

We have proceeded this year on the gas centrifuge schedule as has been outlined to you in our previous testimony. We are, in fact, in the process of a number of awards that I believe you are familiar with, the most significant of which has been the award to the three industrial suppliers, and now competitors, as well, for the large supply of centrifuge machines that will make the gas centrifuge plant a reality in the late 1980's. We are committed to supply enrichment requirements as an assured supplier—that is the basis for national policy—and in so doing, we have been very attentive to projections of nuclear power growth and the factors that are required to assure our posture in the enrichment service business. It has become an even more complex business because of the shifting character of nuclear power demand, but we still believe very positive movement of the industry is possible, with an eventual growth that will serve to make nuclear power a very important base point for our energy supply.

The implications of the operating plant that we have developed will be discussed in some detail by Mr. Voigt, as well as the schedules that we have used for our current diffusion activities and gas centrifuge development and construction program. We believe that this very large enterprise is one that is being treated as a major business effort, both as an element of national policy, and as an enterprise that the Nation can be pleased and proud of. I would like Mr. Voigt to continue testifying with a further description of our activities.

Mr. MCCORMACK. Thank you, Dr. Weiss. Mr. Voigt?

STATEMENT OF WILLIAM R. VOIGT

Mr. VOIGT. Thank you, Mr. Chairman, members of the committee, Congressman Duncan.

I would like to highlight the statement that I have submitted for the record, Mr. Chairman.

During testimony given in February of this year before this committee, we presented our estimate for domestic and non-U.S. nuclear power on line in 1985 which would obtain enrichment services from DOE. These estimates are shown in the first chart.

[Chart 4 displayed.]

This estimate was based on a reactor-by-reactor evaluation of the annual demand for enrichment services. At that time we had forecast that 115 gigawatts of domestic nuclear power capacity and 65 gigawatts of non-U.S. nuclear power capacity would be on line in 1985, which would be supported by DOE enrichment capacity.

The domestic estimates for 1990 included planned reactors which were not then under construction, but which DOE judged would be needed and could be available to meet the forecasted electrical power requirements. The non-U.S. requirements for 1990 were based on a similar consideration, but included only those reactors expected to be supplied under DOE enrichment services contracts. The results of the projection indicated that 185 gigawatts of domestic nuclear power and 100 gigawatts of DOE supplied non-U.S. nuclear power would be on line by the end of 1990.

After 1990, the growth of nuclear power in the United States is less certain. The Energy Information Administration forecasted in April of this year that by the end of the year 1995, the nuclear power capacity in the United States could range from 186 to 224 gigawatts. The maximum sustaining capability of the DOE enrichment complex currently authorized by Congress at 0.25 percent tails assay is 325 gigawatts. As we testified in February, the operating plan assumed that 120 gigawatts of non-U.S. enrichment demand could be supplied by D.O.E. and that we could also supply 205 gigawatts of domestic nuclear power. If this level of nuclear growth is achieved, the entire capacity from the three fully uprated and improved diffusion plants and the 8.8 million separative work units from the gas centrifuge enrichment plant will be fully utilized by about the mid-1990's.

Since testimony before this committee, I think that several events have occurred which could have some important implications with respect to the future of nuclear power.

The first being the Three Mile Island incident and the resultant uncertainty this incident has placed on the future role of nuclear power.

Second, the creation of a Presidential Commission to review the safety of nuclear reactors and the future status of nuclear power in the United States.

Third, for the 52 week period ending August 4, EEI reported a 5.1-percent increase in electrical energy distribution in the United States. A comparable number for the timeframe ending September 2, 1978, was 2.4 percent.

As you well recognize, the first two events that I mentioned have had an effect on the growth rate of nuclear power. In addition, the Nuclear Non-Proliferation Act and concerns over U.S. policies regarding reprocessing and breeder reactor deployment have created an atmosphere of uncertainty relative to the United States as an assured source of supply for enrichment services. The last item that I mentioned, and that is the electrical energy increase, may have some impact upon nuclear power growth, but I think it is uncertain at this point in time to say just what impact it may have.

As uncertain as the future normally is for forecasters, these events have created a future that is extremely difficult to forecast. Nonetheless, we must attempt to develop as reliable a demand forecast as possible in order that we may develop a production plan that will optimize the enrichment complex operating variables. We are now in the process of evaluating the likely effect of these events on future enrichment demand and developing alternate operating strategies to meet varying demand scenarios.

We are also in the final phase, Mr. Chairman, of converting the long-term fixed commitment contracts to what we call adjustable fixed commitment contracts, with all of these conversions to be completed by September 30; that is 8 days from now. The AFC contract allows our enrichment customers considerably greater flexibility to adjust delivery quantities and to reschedule deliveries. About 95 percent of our LTFC's, that is our long-term fixed commitment contracts, are converting to the AFC contracts.

Turning now to enrichment services supply and demand, in addition to the requirements that we have from domestic and nondomestic sources, the U.S. Government and miscellaneous requirements are also provided for through the planning period. Government requirements average about 1 million SWU's per year, and users principally include the naval reactor program, the nuclear research and development efforts, as well as DOE production reactors. We have also included in our plan, miscellaneous requirements such as those needed under short-term fixed commitment contracts. We expect that these will amount to an average of 400,000 separative work units per year. The resulting total demand for DOE enrichment services is shown on this chart.

[Chart 5 displayed.]

As can be seen from this chart, during the early 1980's we are in a preproduction mode whereby material produced is going into a preproduction inventory. From about 1986 through the early 1990's, we have projected demand to be in excess of our current capacity and hence we will be drawing from our stockpile during this period. During the early to mid-1990's we will be maintaining a 14 million separative work unit inventory and bringing the Portsmouth gas centrifuge plant capacity on line in a manner such that supply will equal demand.

In the spring of 1978, when we found that the near-term projected demand for enrichment services was being delayed, the operating plan had to be revised and construction of the gas centrifuge enrichment plant rescheduled. This action was taken to avoid unnecessarily early inventory buildup and the attendant near-term budget expenditures. Accordingly, DOE has negotiated with its power suppliers to reduce power in the 1979 to 1981 timeframe. The resulting enrichment complex operating plan to supply the forecast demands is also shown on this chart.

As I mentioned earlier, production of separative work is expected to be less in the next 2 years than the demand. The difference between these two factors will be made up by drawing from our current inventory. The low enriched uranium inventory levels are shown as a function of time for the current operating plan on the next chart. [Chart 6 displayed.] Whereas we are drawing from the inventory now,

it goes back up during the mid-1980's, getting down to what we call a prudent planning level of 14 million separative work units. Nine million of this inventory is for a working inventory, that material tied up in our large capacity pipelines; the remaining 5 million separative work units have been identified by administration as a possible set aside for international nuclear fuel assurance in response to the Nuclear Non-Proliferation Act.

GASEOUS DIFFUSION OPERATIONS AND EXPANSION

Turning now to diffusion operations and what we are doing in terms of expansion, as I mentioned earlier, the projected power usage in the diffusion plants in the next fiscal year will be well under past years' levels. Consistent with our long-term production planning, we have reached agreements with each of our power suppliers to keep power purchases in fiscal 1980 as low as possible without incurring any demand payments for power not taken. The power to be delivered in fiscal 1980 approximates 3,049 megawatt-years and this will be sufficient to operate the three diffusion plants at the lowest practical power level while still insuring safe operation of the plants. We would expect to produce about 10.5 million separative work units at this power level. We now estimate that our fiscal year 1980 costs for power will be around $613 million.

Mr. McCormack. Excuse me. Where are you in your text?

Mr. Voigt. I'm on page 8 at the top of the page, Mr. Chairman.

Mr. McCormack. Thank you.

Mr. Voigt. This is about $65 million over the amount Congress has appropriated in our fiscal year 1980 budget and reflects our latest estimates of power to be delivered to the diffusion complex. We're now evaluating what options we have to resolve this funding deficit. In addition to this deficit, Mr. Chairman, as I mentioned earlier, we are converting from the LTFC's to the adjustable fixed commitment contracts. We are seeing modifications to the appendices of these contracts which have the potential for reducing the revenues that we were projecting to receive during fiscal year 1980. That projection was $1.3 billion. As of right now, we do not know how much that might be reduced, but we expect it will be reduced.

As part of our commitment to have sufficient capacity to serve existing and future uranium enrichment requirements, two major diffusion capacity expansion programs have been underway for several years. These projects are what we call the cascade improvement program [CIP] and the cascade uprating program. The CIP program, when completed, will increase the capacity of the existing diffusion plants by about one-third or 5.5 million separative work units per year.

[Chart 7 displayed.]

As shown in this chart, at the end of the third quarter of this fiscal year, 2,263 stages have been modified and equipped with new barrier. By the end of this year, we expect the program will be over 75 percent completed. Due to a prolonged strike at the Portsmouth plant, which began in early May of this year and, in fact, is still in progress, the scheduled September 1981 completion date will not be met at that site. The other two sites, however, both Paducah and Oak Ridge, will be completed on schedule.

Turning now to the cascade uprating program, this will increase the capacity of the improved plants by an additional 20 percent or about 4.6 million separative work units per year.

As shown on the next chart, this program was started in 1974 and is on schedule with 2,585 stages uprated.

[Chart 8 displayed.]

The program schedule indicates that over 66 percent of the program should be completed by the end of fiscal year 1979. Again, as experienced in the CIP program, the strike we have at Portsmouth has affected this and completion of the program will probably extend into 1982.

GAS CENTRIFUGE DEVELOPMENT AND CONSTRUCTION

I would now like to turn to our efforts on gas centrifuge development and construction. As you know, the Gas Centrifuge Enrichment Plant, which we call GCEP, is under construction at Portsmouth, Ohio, and the development program is completely oriented toward final development and demonstration of a centrifuge production model for installation in GCEP. The centrifuge program has been around since 1960 and our contractors and field managers have made truly outstanding breakthroughs during the 19 years of sustained progress. Today, among the various countries now engaged in centrifuge development, I would say, Mr. Chairman, that our program is second to none. I am delighted that you could come to Oak Ridge and see for yourself just where we are with respect to not only diffusion technology, but centrifuge technology as well.

We have selected a centrifuge design for GCEP and are now in the final stages of demonstration and qualification prior to production. Our centrifuge is really an impressive piece of equipment, which we believe to be considerably more technologically sophisticated as compared to our European competitors. The size that we have selected to go into the gas centrifuge plant was selected in early 1977, and for the last 2½ years has been undergoing very exhaustive top to bottom testing. Minor design changes are still being tested to confirm improvements to the centrifuge. Prototype models of the GCEP design are currently in various stages of development, testing, and qualification and we are certainly drawing on our previous 19 years' experience in this program.

As in any development program, however, where aggressive plans are being pursued, there will be occasional setbacks. Just last year, several GCEP prototype centrifuges, operating in a reliability test facility here in Oak Ridge, failed and had to be repaired. A team of outside consultants was called in, and they confirmed our own diagnostic analysis. Changes have been made, and the centrifuges are again being installed for operation to provide final proof that we do have a quality machine.

To sum up the centrifuge effort, we are confident that centrifuge technology will be ready for large-scale application in GCEP, and we are pursuing an aggressive development program to insure this goal. In some cases, more than one design choice for a particular component is still being studied to establish if one has any outstanding benefits over the alternate designs. In other cases, a backup design is still being studied, just in case the selected component develops a problem later on. In still other cases, alternate designs are being studied to

make possible more efficient, more productive, and/or more reliable centrifuges for later use.

The commitment by President Carter and his administration to build the gas centrifuge enrichment plant has allowed DOE to assure existing and new enrichment customers that it expects to provide such services at a transaction tails assay no greater than 0.25 percent U–235, a level which conserves the supply of natural uranium. In keeping with that, Mr. Chairman, we have included within our AFC contract a clause which stipulates that if we transact at a tails assay higher than 0.25 percent U–235, the customer has the option to get out of the contract free of charge.

We began facility design on GCEP in March 1978. All of the major architect-engineers have been selected and are actively designing the plant. The present schedule calls for the major facility designs to be completed in mid-1982.

[Chart 9 displayed.]

This chart displays all the major architect-engineers and the status of their respective efforts.

The GCEP project has advanced to the construction stage and the construction manager/constructor, that being Stone & Webster Engineering Corp., has been selected to manage the work.

[Chart 10 displayed.]

This chart depicts the construction status as well as site preparation activities. An award has been made for the foundation for process building No. 1 as well as for the procurement and erection of the structural steel for the first process building. Other major construction actions include the award of long electrical equipment purchases.

The phase I centrifuge manufacturing contracts, that being the Boeing, Goodyear, and Garrett, have been selected and are under letter contracts. As you know, Boeing will be breaking ground today for the machine manufacturing plant. Negotiations with these firms are proceeding well, such that definitive contracts are likely to be in effect by the end of this calendar year. The first qualification machines are scheduled for delivery to the centrifuge plant demonstration facility in October 1980. This facility is expected to go operational in 1982, and this will be the first testing of a full production cascade prior to implementation into GCEP.

To date, the GCEP project has incurred costs of approximately $180 million and has additional commitments totaling in excess of $300 million.

In summary, Mr. Chairman, I believe that the DOE fiscal year 1980 authorization and appropriation requests as submitted to Congress will permit the continued maintenance of the GCEP progress fully in accord with the goals and objectives of all concerned, and that the harmonious efforts of both the administration and Congress are responsible for the gratifying GCEP progress to date.

This completes my discussion, Mr. Chairman, and I would be happy to answer any questions you might have.

Mr. McCormack. Thank you, Mr. Voigt.

Mr. Voigt, I am sure that the committee members are a little overwhelmed by the array of figures, and I always find myself having to go back and get my feet on the ground. I wonder if you could, just in conversational terms, give us a picture now of exactly where we are and where we expect to be. What is our production capacity today in the diffusion system, what will our production capacity be when we

have the new centrifuge plants on the line, and what will those dates be, and then equate them at some point with the number of 1,000-megawatt nuclear plants. Could you do that in sort of a casual manner?

Mr. VOIGT. Very casual.

We are projecting that in fiscal year 1980, we will be producing on the order of 10.5 million separative work units. When the plants are fully powered, and following completion of the cascade improvement and uprating programs that I mentioned earlier, the plants will have the capability of producing on the order of 27 million separative work units per year. This is expected by the early 1980's.

Mr. MCCORMACK. This is all diffusion so far.

Mr. VOIGT. That is all diffusion.

Mr. MCCORMACK. That is all three facilities, Portsmouth, Oak Ridge, and Paducah.

Mr. VOIGT. That's correct.

Mr. MCCORMACK. 27.5 million separative work units.

Mr. VOIGT. 27.3; yes, sir.

Mr. MCCORMACK. In the early 1980's.

Mr. VOIGT. I'm sorry?

Mr. MCCORMACK. In the early 1980's.

Mr. VOIGT. In the early 1980's; yes, sir.

With the advent of GCEP, we expect to have 2.2 million separative work units on line in fiscal year 1988, with the remaining 1.1 million separative work units to be added as demand so dictates. So, from a planning standpoint, we are assuming that the full 8.8 million separative work units out of GCEP——

Mr. MCCORMACK. I beg your pardon?

Mr. VOIGT. From what we have presently projected from a planning standpoint, the full 8.8 million separative work units from GCEP will be on line in 1993. This will bring our total capability up to approximately order of 36 million separative work units per year.

Mrs. BOUQUARD. Would you repeat that, Mr. Voigt?

Mr. VOIGT. Having achieved the full 8.8 million separative work units out of the Gas Centrifuge Enrichment Plant in 1993, as we are presently projecting, this will bring up out total production capability to 36 million separative work units per year. That is the 27.3 plus the 8.8.

Mr. MCCORMACK. Can you relate the 36.1 million separative work units to 1,000-megawatt plants?

Mr. VOIGT. That capability can sustain 325 gigawatts at a 0.25 percent U-235 tails assay.

Mr. MCCORMACK. At what?

Mr. VOIGT. 0.25 percent U-235 tails assay.

Mr. MCCORMACK. How much of that 325 gigawatts will, at that time in the early 1990's, be a foreign commitment?

Mr. VOIGT. We are assuming that one-third of that capacity is non-United States, for example, about ——

Mr. MCCORMACK. About 220 gigawatts.

Mr. VOIGT. About 205 gigawatts domestic, the remaining 120 gigawatts would be foreign.

Mr. MCCORMACK. It strikes me that that is a fairly conservative estimate for demand at that time and I am curious to know how you reconcile that with the administration's projections of up to 395 one-gigawatt plants as the high projection for the year 2000, which is

only 7 years later. That would be 175 plants, the capacity of an additional 175 gigawatts in 7 years.

Mr. VOIGT. As I indicated, Mr. Chairman, the Energy Information Administration forecasted in April of this year that by the end of 1995 the projected nuclear power capacity in the United States would be somewhere between 186 and 224 gigawatts.

Mr. MCCORMACK. 186 and 224?

Mr. VOIGT. Yes; that being the high and the low.

Mr. FLIPPO. Can you translate that into plants?

Mr. VOIGT. Normally considering about 1,000 megawatts per plant, that would say there would be 186 to 224 plants.

Mr. WEISS. Let me add one thing, Mr. Chairman.

Mr. MCCORMACK. Yes, go right ahead, Mr. Weiss.

Mr. WEISS. The gas centrifuge is designed such that capacity can be added on a modular basis. That's why we speak of this 2.2 million separative work units as our first increment and on a planning basis reaching the 8.8 million separative work units in the early 1990's. One of the very favorable aspects of that design is that the leadtime to installation is significantly less than the leadtime to installation of nuclear powerplants. Thus, our capability of scheduling additions to the plant can go right along with the advancement of our nuclear power projections. We estimate that comfortable leadtime for increments of gas centrifuge capacity is about 6 years. Certainly we would hope that as requirements for nuclear power were expanded, the current leadtimes of up to 12 years or so for a nuclear powerplant would be markedly reduced, but the capability of gas centrifuge certainly is well in advance of any planning that we have for nuclear powerplants. Therefore, our capability of meeting enrichment demand is there.

Mr. MCCORMACK. I am encouraged by that fact. What you seem to be saying is that whatever the projections for expansion of nuclear powerplant are, that if the leadtime is 6 years or more, that enrichment capacity can keep up with the demand.

Mr. WEISS. Yes, that's correct.

Mr. MCCORMACK. This is reassuring. I find the projections of 186 and 224 gigawatts by the year 1995 to be, I think, extremely unfortunate because there isn't anyway in the world we can close the gap between supply and demand with that low a number of nuclear plants even if we assume tripling coal production between now and that time. Between now and the year 2000 there isn't anyway of meeting even the minimum requirements of the President's goal and so I think I should submit for the record the point that whereas we are delighted that we are going to be getting the centrifuge program going, there isn't any doubt about the fact that it is going to have to be expanded at a substantially greater rate in the mid-1980's than the projections are today, if we are to be coming anywhere close to having enough energy for this country.

Mr. WEISS. We believe our plant can sustain that.

Mr. MCCORMACK. Thank you. Mr. Roth?

Mr. ROTH. I have no questions, Mr. Chairman.

Mr. MCCORMACK. Mrs. Bouquard?

Mrs. BOUQUARD. Thank you very much, Mr. Chairman.

I recall our cutback in the centrifuge program, I think it not only jeopardizes our domestic needs, but it also is a move to foreclose our capacity, our capability for enrichment contracts for foreign utilities and also to provide adequate material for an international diffusion bank. So I am very concerned about this. I think we should all realize that these plants may not be able to operate at full capacity because of the Iranian oil situation as well as coal strikes that we have experienced in our part of the country.

I would like to ask a question. We do appreciate your testimony. I think you have a copy of my amendment that I intended to offer to the DOE bill. You will be provided with a copy of this. This does not provide any additional funds because we still have money for the enrichment, provided for enlarging the capacity at Portsmouth, so we are not talking about money.

I think basically what it does, is that it gives us some data so that we won't say what we're going to have from 1 year to the next year, so that we have something concrete and reliable that we can work on. And I think that is what this amendment is aimed at. I was wondering if you have any points—we want to know where we are going, what the actual commitments will be in the long-term plans for the enrichment program.

Mr. WEISS. I'll give a start. Mr. Voigt may have something in addition.

I had a chance to go over the points, and I think all of the reporting requirements that you have noted appear to be very reasonable and data that we will be very capable of supplying because they are elements of our own business projections and planning. The one question that I feel will be an element of policy decision is your item 7, which deals with the involvement of the private sector in the enrichment process.

Mrs. BOUQUARD. I think that is a worthy comment.

Mr. WEISS. I believe that at this time I can only note that it is the one area that reflects true policy considerations as such that are from time to time looked at by the administration, and certainly the view of the administration on private sector involvement will bear comment as each budget is submitted.

Mrs. BOUQUARD. This is the section that deals with encouraging the private sector to become involved, but also under A, I'd like some clarification from you, if I may, Mr. Voigt, on the impact of domestic uranium production capabilities and source on the enrichment operation, including constraints on uranium production due to land withdrawals. The estimates that you give do include land that we do have, forest area, wilderness area, and Chattanooga shale, don't forget that.

Mr. VOIGT. So far as I am concerned, we will be most happy to comply with each and every one of the items listed here. As with respect to your point 8, we will include within our reserves and resource estimates that quantity of which is on land which has been withdrawn, and we have supplied to Congress from time to time our estimate of what these resources would do in relationship to land withdrawals in Alaska, with respect to the Rare-II lands, and with respect to all lands that have been withdrawn from mineral exploration.

Mrs. BOUQUARD. Thank you very much, Mr. Chairman.

Mr. MCCORMACK. In respect to Mrs. Bouquard's question, can you give us the number of tons of U_{235} that is required to produce 3

percent enriched uranium to .2 percent tails using 36 million separative work units? If you cannot do that today, could you give it to us in writing later?

Mr. VOIGT. I will be most happy to.

[The material follows:]

The quantity of natural uranium required to be fed to the enrichment plants is a function of enriched product assay, separative work availability and the enrichment plant tails assay. Assuming a typical enriched product assay of 3% U-235, the quantity of natural uranium needed to sustain an annual enrichment capacity of 36 million SWU's is described below as a function of enrichment plant tails assay:

	Tails assay—percent U-235		
	0.20	0.25	0.30
Short tons of U_3O_8 needed for 36,000,000 SWU	59,500	73,200	89,800

Mr. MCCORMACK. I think that is a very important thing for us to have at our fingertips for analyzing the question.

Mr. Roth?

Mr. ROTH. Mr. Chairman, I was not going to ask a question because of the time element, but I would like to ask this. I think it is very important if the projections or goals that you are setting forth are not satisfactory. What I would like to know is where does the burden lie, does it lie with our technology, with our environment or does it lie with the political or policy decision? What I am getting from you is while they may not be satisfactory, you give us 6 or 12 years and we can always catch up. Is that a correct assessment of what you are saying?

Mr. WEISS. I hope not. The assessment, I would hope, is that we are trying to operate the enrichment business in a prudent and flexible fashion. The prudence lies with having the capabilty to meet demand without excessive inventories. The flexibility lies in our capability to install enrichment capacity as demand projections increase. We have seen in the past year a marked decrease in demand, which from a business standpoint we hope to see as an upturn in the near future. But to date and especially in recent months, we have seen decreases in projections which we believe from a business standpoint suggest a matching of our production with this demand, retaining the capability of extending our enterprise with a great residual capacity which we are certainly evidencing now to meet any expanding demands.

Mr. ROTH. Well, Mr. Chairman, that is still rather nebulous in my opinion, because we could get a downturn and next month we would have an upturn and it all depends on what the public opinion is going to be.

Mr. WEISS. We believe we have substantial residual in both our inventory and our ability to add SWU generating capacity by virtue of the large difference between our production planning and the capacity that we noted. I guess the other aspect of that answer is that we are maintaining a very dynamic projection analysis on a reactor-by-reactor basis and this is updated each month. Unfortunately that projection has resulted in decreased demand forecasts in each month this year but, you know, our aim is to remain on top of that.

Mr. MCCORMACK. Mrs. Bouquard?

Mrs. BOUQUARD. Mr. Chairman, in the interest of time, I do have some additional questions that I would like to submit for the record.

Mr. MCCORMACK. Without objection. Mr. Flippo?

Mr. FLIPPO. Thank you, Mr. Chairman.

I have two very brief questions. First of all, I would like to know if the change from the LTFC type of contract to the AFC contract, has any immediate or near term budget impact. Would that increase the costs or does that decrease our needs for the future, or what does that do for us?

Mr. VOIGT. In terms of the short term, we expect it to result in a variance in the near term revenues that we are projecting to receive. As I mentioned, our projections for fiscal year 1980 were that we would receive $1.3 billion in revenue from the sale of our enrichment services. Each of the people that we are contracting with has the capability to change the appendix of their contract prior to September 30 of this year. We expect that the revenues that we were projecting for fiscal year 1980 are going to be reduced and, hence, that does present a problem from a funding standpoint because our revenues offset our costs.

Mr. FLIPPO. All right. Of course, one of the things that increases the costs is uncertainty and there is an adequate amount of uncertainty to go around in projections of any kind of demand in this uncertain world we live in. Could you suggest to this committee some things that we might be able to do or that we could be working toward to reduce the uncertainty with which you have to deal?

Mr. VOIGT. The greatest uncertainty, I think, with respect to——

Mr. FLIPPO. May I interrupt you to say if you think of anything further after this hearing today that you could submit that in writing.

Mr. VOIGT. I'll be most happy to.

Mr. FLIPPO. Thank you.

Mr. VOIGT. We are seeing a number of foreign contract holders terminating their contracts with us. In my viewpoint, this is being caused by two considerations; one being from the standpoint of their desire to have a diversity of supply in enrichment services. However, a second point is with respect to the Non-Proliferation Act that was passed by Congress. There is a great deal of concern on the part of foreign utilities as to whether they can receive an export license for getting material out of this country. In my discussion with these foreign utilities and their top executives, they have expressed that one of the reasons that they are terminating contracts with us is their concern over the Non-Proliferation Act and hence the capability of getting material. So from that standpoint, I think Congress could be helpful.

Mr. FLIPPO. Thank you very much for your reply.

The licensing procedures to export material and licensing procedures to license construction of breeder reactors and some other things, I think might be some areas of exploration for us that will be highly profitable for the country.

Thank you, Mr. Chairman.

Mr. MCCORMACK. Thank you. Mr. Duncan?

Mr. DUNCAN. Just one, Mr. Chairman.

You indicate that you are going to have a shortfall in money because of the cost of the fuel. Does that relate to the increase in the cost of fuel to cause the shortfall you had indicated, the increased cost of power, how does that relate to the shortfall that you anticipate.?

Mr. VOIGT. Congressman Duncan, we are experiencing two problems in relation to the fiscal year 1980 budget. One is an increase in the cost of power that we use at the diffusion plant, and this is principally as a result of the TVA price increase.

Mr. DUNCAN. How much is related to the increase in the cost of power?

Mr. VOIGT. It is $65 million. All this is related to increases in the cost of power. The other problem I was discussing was the loss of revenues, which are used to offset our costs.

Mr. DUNCAN. Mr. Chairman, there is one other question, if I may.

I understand that you plan to reduce the advanced isotope separation technology down to one at the end of fiscal year 1981. What is the basis for that—centrifuge?

Mr. WEISS. Could you restate your question in terms of the centrifuge or is your interest with the AIS?

Mr. DUNCAN. It is my understanding that you plan to narrow the advanced isotope technology down to one at the end of fiscal year 1981, and I was wondering if you could give us the basis on that. Why you consider it wise and the cost effect.

Mr. WEISS. We may have some more discussion on that. I have a limited knowledge because the advanced isotope separation is not part of our organizational responsibility.

The intent, however, is to restage the advanced isotope separation activity to where we can proceed in the nearest term toward viable commercial use of advanced isotope separation. If that involves concentration on a particular technology, if that is indicated by the work up to that point, then that's the way; if it isn't, then we will carry on the development and the research until we can make that judgment.

Mr. DUNCAN. Thank you. Thank you, Mr. Chairman.

Mr. MCCORMACK. Thank you.

Mr. VOIGT. Congressman Duncan, I think Dr. Merriman will be discussing each of the three processes that are now being pursued in the advanced isotope separation technique.

Mr. MCCORMACK. One very quick question. Isn't DOE obligated to increase the cost of enrichment to consumers in the case of increased costs, so that you are running at a zero profit and zero loss situation?

Mr. VOIGT. By statute.

Mr. MCCORMACK. Why does the $65 million raise any question?

Mr. VOIGT. By statute, Mr. Chairman, we are required to recover all our costs over a reasonable period of time, hence, from that standpoint any cost increases would be passed on to the people. The fact is that when we seek budget authority from Congress, we seek a net budget authority. Because of the increased power cost and decreased revenues, the net budget authority has to go up, so that is why we are looking to see if we can solve our problem internally. If not, we may have to come back to Congress for some help.

Mr. MCCORMACK. But it is still a zero balance operation as far as Congress is concerned, isn't it?

Mr. WEISS. I think there is one aspect to that that makes it not so. The costs that we develop as they relate to our pricing are based on a campaign period and not on a simple annual basis of recovery of annualized costs. The campaign period is a 10-year period in order to average out the differences which occur on a year-to-year basis so that one year does not provide a very high cost of SWU's and another

year a very low cost. This is necessary not only from the standpoint of providing reasonable planning for domestic utilities, but also to retain our competitive posture in the international market. A 1-year impact such as we are talking about now will be reflected over a 10-year campaign period.

Mr. McCormack. I want to thank you gentlemen. I have a number of other questions and I suspect that other members of the committee do also. We have already run over our allotted time and we will submit them in writing and I trust you gentlemen will entertain questions that we submit in writing and attempt to get us answers in a reasonable time.

Mr. Weiss. We will be very pleased to, Mr. Chairman.

Mr. McCormack. I am going to put you on the hook indirectly by inviting anyone in the audience who wishes to submit questions on this subject to do so in writing to the committee, not to the witnesses. The committee will receive your questions or suggestions or recommendations or analysis of the situation and attempt to integrate and consolidate it into a series of comprehensive questions to submit to the administration. In this way, we take advantage of your expertise to perhaps improve our own understanding of the entire situation and we will appreciate your contributions and questions.

Thank you, gentlemen, very much.

Mr. Weiss. Thank you, Mr. Chairman.

[Questions and answers follow:]

Questions Based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

1. It appears that the Administration's policy is to draw from our presently mined uranium inventory until we bring it down to the level corresponding to 14 MSWU. On what basis was it determined that 14 MSWU is adequate? What factors in this determination most sensitively affect the resultant answer? How much would it cost the country to do that, as opposed to keeping the reserves at 25 MSWU in 1982 and speeding up the centrifuge development program to meet the needs from 1983 to 1990?

Answer:

Basis of the 14 MSWU Target Inventory

The specific uses of the low enriched uranium (LEU) inventory are to:

- Meet projected demand in excess of projected production. These excess needs are primarily related to initial cores of nuclear power reactors which require about double the enrichment services of annual reloads.

- Provide a working inventory containing 9 MSWU at the enrichment plants.

- Provide a strategic inventory containing 5 MSWU.

On June 30, 1979, the LEU inventory contained about 31 MSWU. Current demand projections indicate that by the end of the 1980's, the LEU inventory will be reduced to the 14 MSWU level required for working and strategic needs. The decrease to 14 MSWU is gradual, thus, providing some flexibility to alter the long term LEU inventory level if future events should warrant.

The 9 MSWU working inventory is necessary to serve as a buffer between daily production of enriched uranium and the day-to-day shipments of finished product to the en-

richment customers. At full production, DOE would have to supply the requirements of well over 300 power reactors each year with each customer requiring up to eight different assays of enriched uranium. In addition to power reactors, DOE must supply the enriched uranium needs of naval propulsion reactors, numerous test reactors, research reactors, as well as the needs of other Government non-power programs. To assure that all of these requirements can be met in an orderly fashion requires that a working inventory of sufficient size be available.

The size of the working inventory is dependent on two factors:

- The time physically required to prepare and deliver enriched uranium to the customer. Based on past experience, we estimate that it will require about 30 days from time of withdrawal of enriched product until it is available for shipment to the enrichment customer.

- The operating flexibility needed to assure that the customer's delivery dates can be met as agreed to under the terms of the enrichment services contracts. Statistical analysis on past delivery patterns indicates that a 60-day production reserve will assure with high confidence that orders in excess of the average monthly demand in any single month could be filled promptly.

The total working inventory requirement thus equals about 90 days of production--30 days for the lead time required for product preparation and another 60 days as a reserve to protect against excessive ordering in a single month. When the fully improved and uprated production levels for the existing plants and full production from the new Gas Centrifuge Enrichment Plant (GCEP) are achieved, the total 90-day working inventory will be equivalent to about 9 MSWU.

A strategic inventory could be needed to further potential non-proliferation policies and programs. The Nuclear Non-Proliferation Act (NNPA) (P.L. 95-242) of 1978 pro-

posed exploring establishment of an International Nuclear Fuel Authority (INFA). One facet of INFA would be that it would control a stockpile or Bank of LEU to provide additional guarantees for those countries which adhere to strict policies designed to prevent proliferation. Additionally, a strategic inventory might be used in support of other fuel assurance mechanisms, such as some of the bilateral or multilateral arrangements which are under consideration in INFCE and elsewhere. Based on the various scenarios analyzed, 5 million SWU appears to be the maximum amount that would be needed to meet U.S. commitments to INFA.

Cost of Obtaining a 25 MSWU LEU Inventory

It doesn't appear at this time that the initial increments (i.e., first two buildings) of GCEP can be accelerated significantly. However, construction of the remaining six buildings could be accelerated such that the entire 8.8 million SWU of GCEP capacity could be on-line about two years earlier than currently planned (i.e., 1991 rather than 1993). Accelerating GCEP in this manner by itself, however, would not be adequate to obtain a 25 MSWU LEU inventory. It would also be necessary to increase the operating tails assay of the enrichment complex. The additional natural uranium needed could be obtained either by direct purchase from the uranium industry or by increasing the transaction tails assay to 0.25% U-235 from the present 0.20% U-235 level sooner than currently planned, thereby, requiring customers to deliver to DOE substantially greater amounts of natural uranium. The transaction tails assay determines the quantity of SWU to be purchased and the quantity of natural uranium to be provided by customers in order to obtain their desired enriched uranium quantities. Using the February 1979 operating plan data base, the transaction tails assay change would need to occur in FY 1991 or 4 years sooner than in the February plan. Outlays associated with obtaining the additional natural uranium would be the major cost of maintaining the inventory at 25 MSWU and would amount to about $2 billion at today's prices.

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Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

2. Exactly what are the projected revenue losses the Nation might incur in the short term, due to changing from the Long Term Fixed Commitment (LTFC) contracts to the Adjustable Fixed Commitment (AFC) type contract? How large are the error bars in this type of projection?

Answer:

In 1978 the contracted commitments for uranium enrichment services greatly exceeded the actual needs. The AFC contracts were offered in July 1978 to provide customers with flexibility to more closely match contract commitments with actual needs, to enhance the U.S. competitive position in the world enrichment market, and to support U.S. non-proliferation goals. By providing the opportunity for our present customers to adjust their future enrichment services requirements (for a fee) to more evenly balance supply and demand, large excess stockpiles of enriched uranium will not be built up.

Permitting customers to convert their LTFC contracts and adjust their delivery schedules resulted in a loss of near-term revenues. At the same time the reduced demand allowed DOE to modify its operating plans. Planned production levels were significantly reduced with corresponding cost savings. For example, FY 1980 production was held as near the minimum level as possible. As a result of these cost savings and the deferral charges received from the AFC customers, there was little, if any, impact on net budget requirements in FY 1980 due to the contract conversions. Moreover, in the long run, the net effect of the AFC adjustments on demand will be small since LTFC customers would eventually have adjusted their future delivery schedules (thus affecting future DOE revenues) to compensate for the surplus inventory of enriched uranium that had and would have continued to accumulate for some time under those contracts.

The FY 1980 revenue budget of $1,310 million was based on estimates of demand after the LTFC to AFC conversions and on estimates of demand under Requirements Contracts. With firm up of the AFC conversions and associated requirements on September 30, 1979, the FY 1980 revenue estimate for AFC contracts was reduced by $63 million as some customers slipped more than previously estimated. At the same time Requirement Contract demand slipped due to the NRC licensing moratorium, reactor startup problems and extended maintenance downtimes. Accordingly we now expect sales from these customers to be $190 million below the budget level. Sales to Requirement customers are still not absolutely certain as they are required to firm up deliveries only 180 days in advance. At this time, however, the total FY 1980 revenue budget estimate has been reduced $253 million to a revised level of $1,057 million. This shortfall in addition to increases in the cost of cascade power (discussed in the next question) will require supplemental appropriations during FY 1980.

At present, all AFC deliveries are firm for FY 1980 and 1981; firm estimates have also been received for FY 1982 and FY 1983, but upon payment of schedule adjustment charges, deferral of deliveries scheduled for these years are still possible; FY 1984 and FY 1985 deliveries have a $\pm$ 10% and $\pm$ 20% uncertainty at present, with firm-up required by July 1980 and July 1981, respectively. Nonbinding estimates for deliveries past FY 1985 have also been received. As mentioned previously, Requirements contract deliveries which comprise about 1/3 to 1/2 of the total projected deliveries over the next ten years are firmed up only 180 days in advance of delivery. Thus there is a considerable uncertainty associated with projected needs under these contracts.

Questions Based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

3. Please provide more information on the projected need for $65 million more to operate the present gaseous diffusion plants in FY 1980 than had already been appropriated. Exactly what measures are being taken to decrease this projected deficit? If one went to a shorter "campaign time" than the 10 years Dr. Weiss mentioned, might that not allow for a quicker recovery from this type of deficit? How would a shorter "campaign time" affect the marketability of our enrichment services?

Answer:

The FY 1980 Congressional submission estimate for cascade power for the gaseous diffusion plants was $532.55 million. The current estimate for cascade power in FY 1980, is $613 million. Congress has appropriated $548.34 million which leaves a projected deficit for the fiscal year of $64.66 million. This deficit is the result of:

- Higher unit costs of power announced by our suppliers (primarily TVA) than costs used in the preparation of the FY 1980 budget. Power rate increases will add $16.45 million to the appropriated level.

- Under letter agreements between DOE and TVA, DOE has the right to reduce TVA's power deliveries by 6000 MW-MO over the seasonal periods in FY 1980. TVA has the option to expand this reduction to 8000 MW-MO. The FY 1980 Congressional budget assumed that TVA would elect to exercise their full seasonal power option of 8000 MW-MO. Current projections are based on TVA not exercising this option which would increase the power budget by $34 million.

- Increases in the cost of pollution control financing and maintenance within the OVEC system. This will increase the OVEC power cost $14.21 million above the budget level.

The deficit could be reduced if TVA elected to expand the amount of seasonal power not delivered to DOE. TVA has the option to expand the seasonal power reductions four times in FY 1980, in December 1979, March 1980, June 1980, and September 1980. If TVA elects to expand the seasonal power reductions on all four occasions, the budget could be reduced by $34 million. At this time, TVA has not provided DOE with any indication that they will expand the seasonal power delivery reductions. The only other option DOE has considered at this time is to request a supplemental appropriation to cover the deficit.

The pricing methodology uses a 10 year pricing period to arrive at a levelized uranium enrichment charge. Shortening the pricing period could increase or decrease the price depending on the period selected. There are a number of opposing variables that account for this situation. For example, shortening the pricing period lowers the amount of sales which increases the price, however, large out year cost items (primarily GCEP) are removed from the pricing calculation which lowers the price.

Our pricing policy, as approved by Congress and reviewed by GAO, is to arrive at a price which recovers the Government's costs in a reasonable and equitable manner. Manipulation of the pricing period solely to satisfy a given year's budget situation is without precedent and could be harmful to meeting our goal of providing enrichment services on an economical and reasonable basis.

An arbitrary change in the pricing period could impact our marketing efforts. One of our major marketing tools is the price advantage we hold over our competition. We are concerned that any effort to artifically manipulate the price could result in customer perception of DOE's pricing policies as unstable and capricious. That perception would adversely impact our marketing effort.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

4. Please discuss the enrichment sales of Techsnabexport of the Soviet Union. In particular, describe the quanity, quality, reliability, and price of their enrichment services. On the basis of the considerably different prices offered by the various international suppliers, to what extent does price seem to influence an international customer in his selection of suppliers? Does this experience indicate that the U.S. could, if authorized by Congress, retain customers if it charged more than the full cost recovery?

Answer:

As far as we understand, over the next ten years Techsnabexport will sell between about 2 and 4 million separative work units (SWU) per year to non-Soviet bloc countries. To our knowledge, they are providing these enrichment services reliably at a charge about 5 percent lower than the announced DOE charge for enrichment services.

We do not believe that customers for enrichment services buy only on the basis of price, although it is a considerable bargaining tool in discussions with potential foreign customers. We think that other reasons are probably as important to the customer--e.g., reliability of supply, terms and conditions under which the services are offered, and desire to diversify the supply. Furthermore, it is unlikely that countries that have an indigenous enrichment supply will go elsewhere irregardless of economics. Charging customers on the basis of more than full cost recovery, of course, will reduce our international competitiveness. We do not know at which level price would become the principal criterion for choosing a supplier. Certainly a pricing policy, other than full cost recovery, which resulted in a substantial increase in the charge, would be of major concern to our non-U.S. customers. Some of these customers might then consider terminating our enrichment services contracts in favor of foreign suppliers.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

5. During the FY 1979 authorization process, the Senate Energy Committee inserted a requirement for a comprehensive statement of U.S. enrichment policy to be made available by February 1979. Has this plan been developed? If so, has it been made available to Congress, and if not, why not?

Answer:

Section 114 of S. 2692, as reported by the Senate Committee on Energy and Natural Resources, did require DOE "to prepare a full and complete statement of the Department's policy governing civilian uranium enrichment services and an associated plan for civilian uranium enrichment operations through 1990, with appropriate projections to the year 2000." Even though this requirement was not included in final Congressional legislation, DOE staff did prepare a draft report based on the information and assumptions used to develop the FY 1980 budget request to Congress. At the time the draft report was undergoing internal review, additional slippages beyond those anticipated at the time of the FY 1980 budget submission had occurred. Furthermore, the Three Mile Island accident occurred at about that same time adding additional uncertainty to projections of the size of the future enrichment market. Since the report was not officially required by Congress and would have required substantial updating, it was decided not to issue it especially in light of the added and continuing uncertainty with respect to future nuclear power growth and the associated demand for uranium enrichment services.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

6. As the Department is no doubt aware, the Senate Energy Committee has reintroduced this enrichment policy and plan requirement in the FY 1980 authorization. How does the Department plan to respond to this requirement?

Answer:

The Department will comply promptly with any such reporting requirement. Furthermore, we would be pleased at any time to review informally or formally with Congressional members and/or their staffs data and analyses which backup Departmental plans and policies.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

7. Based on the September 22 testimony, the DOE contemplates a sufficient amount of enriched uranium to support a nuclear power production level of 325 GWe, (at a tails assay of 0.25%) from the existing and authorized complex. Please respond to the following:

    a. What enrichment facility capacity is assumed to be sustainable? Does DOE have firm power commitments through 1990 to meet its production plan? What impact have severe winters and power outages had on enrichment production in the last 10 years? How has this contingency been accounted for?

Answer:

About 33 of the 36.1 million SWU annual U.S. enrichment capacity that is currently authorized is assumed to be available to serve nuclear power industry needs. The remainder is capacity set aside for Government programs as well as gaseous diffusion capacity not expected to be generally used because of unavailability of power. The latter category is comprised of two parts: (1) expected shortfalls in contract power deliveries based on historical experience, and (2) exclusion of a block of CUP power, not yet under contract, which may not be purchased because of high cost.

With the exception of a 320 megawatt block of CUP power at Portsmouth, DOE has firm power commitments to supply gaseous diffusion plant needs into the 1990's. These firm commitments are the basis for the long range gaseous diffusion plant production levels assumed in our operating plan.

A summary of annual firm power deliveries to the gaseous diffusion plant sites is as follows:

GDP CONTRACT POWER COMMITMENTS
(MW-YEARS)

	Oak Ridge 1/	Paducah	Portsmouth	Total
FY 1980	950	1356	743	3049
FY 1981	998	1271	1200	3469
FY 1982	1600	2300	1931	5831
FY 1983	1600	2300	1940	5840
FY 1984	1902	2619	1940	6461
FY 1985 & BEYOND	2180	3040	1940	7160

1/ Includes about 75 MW-years in each year which is for ORNL and Y-12 use.

Coal strikes, emergency power shortage situations, etc. have resulted in a shortfall in contract power deliveries of about 4 percent since 1970. The statistical data are shown in the attached Table 1. It should be noted that these data do not reflect power which was not delivered by TVA in the 1970's wherein TVA exercised its contractual right to defer providing certain increments of power until prescribed levels of TVA system generating capacity were attained. Given the present status of TVA power plant construction schedules, this type of occurrence is not likely to be a factor in future years.

The above power shortfall experience is factored into our operating plans. Currently, this is done by adjusting downward our gaseous diffusion plant production estimates assuming that a 4 percent reduction in contract power deliveries will occur.

TABLE 1

HISTORICAL POWER SHORT-FALLS

		PLANT USAGES		POWER LOSSES	
		Average Power Level	Power Consumed	Power Loss	Reason
		MW	10^6MW-HR	10^6MW-HR	
FY	1970	1933	16.9	-	
	1971	2098	18.4	1.0	Assist Con Ed + Midwest Utilities
	1972	2626	23.0	.1	EEI Coal Shortage
	1973	3227	28.3	-	
	1974	3278	28.7	.6	OVEC Station Outage
	1975	3665	32.1	1.8	OVEC Station Outage + TVA Coal Shortage
	1976	4603	40.3	-	
	TQ	4872	10.8	-	
	1977	4931	43.2	.6	TVA Power Shortage
	1978	3886	34.0	8.5	TVA Power Shortage + Coal Strike
	1970-1978		275.7	12.6	

$$\text{Unavailability Factor} = \frac{12.6}{275.7 + 12.6} = .04$$

$\therefore$ Availability Factor = .96

7b. What total capacity of nuclear generation could be sustained if tails assay were maintained at 0.20%? At 0.15%? Please provide the annual uranium enrichment and uranium feed requirements (in tons of U_3O_8) in 1980, 1985, and 1990, for an assumed tails assay of 0.25%, 0.20%, and 0.15%. Do current enrichment customers have any option to conserve on uranium supply by requesting lower tails?

Answer:

If the tails assay were maintained at 0.20% U-235, about 285 GWe could be sustained whereas at a 0.15% U-235 tails assay about 245 GWe could be sustained.

The 1980, 1985 and 1990 uranium enrichment and uranium feed requirements corresponding to the demand assumed in preparing our February testimony are summarized below for assumed tails assays of 0.15%, 0.20%, and 0.25% U-235.

ANNUAL SWU AND URANIUM REQUIREMENTS[1/]

	0.15% U-235		0.20% U-235		0.25% U-235	
	Millions of SWU	Short Tons U_3O_8	Millions of SWU	Short Tons U_3O_8	Millions of SWU	Short Tons U_3O_8
1980	14.0	18,800	12.1	20,200	10.7	22,000
1985	28.9	39,400	25.0	42,400	22.1	46,100
1990	41.9	56,500	36.2	60,900	32.0	66,200

1/ Includes Government Requirements

Beginning with deliveries in FY 1981, Adjustable Fixed Commitment (AFC) contract customers will have an option called the Variable Tails Assay Option (VTAO), to choose a transaction

tails assay different than the current 0.20% U-235 tails assay. VTAO permits customers, with a 15 month notice period prior to the fiscal year in which the option is to be exercised, to adjust the amount of enriched product they take by letting them alter their natural uranium feed delivery schedules. However, this option does not permit the customers any additional flexibility to alter their SWU quantities or delivery schedules. Thus, only to the extent that customers may have excess enriched product can this option be used to conserve uranium supply by choosing a lower transaction tails assay. For FY 1981 deliveries, AFC customers were permitted to choose a transaction tails assay in the range of 0.16 to 0.30% U-235. Only 3 customers elected to exercise VTAO for FY 1981 but we expect more customers will use this option in future years.

7C. In order to provide a better handle by which to grasp DOE's calculations, please indicate how many tons of 3% enriched (.2%) UF_6 can be produced with the projected 36 million SWU's of enrichment capacity targeted to be on line by 1993. How many tons of U_3O_8 must be dug from the ground to correspond to this tonnage of enriched UF_6? What are the same answers if one went to .25% tails?

Answer:

36 million SWU of capacity at a 0.20% U-235 tails assay would produce 12,370 metric tons of UF_6 (8,360 metric tons of uranium) enriched to a uranium assay of 3% U-235. This same enrichment capacity at a 0.25% U-235 tails assay would produce 13,970 metric tons of UF_6 (9,450 metric tons of uranium) enriched to a uranium assay of 3% U-235. Annual feed requirements corresponding to the above would be 59,500 short tons of U_3O_8 at a 0.20% U-235 tails assay and 73,200 short tons of U_3O_8 at a 0.25% U-235 tails assay. About two thirds of this uranium would be from the U.S. toll enrichment customers. The 40,000 to 50,000 tons of U_3O_8 or so required could be produced from domestic resources with diligent development of U.S. uranium production capability.

7d. Show how failure to fully power the enrichment complex in FY 1981 impacts the supply projections indicated in the testimony.

Answer:

The impact of fully powering the gaseous diffusion plants beginning FY 1981 on the February 1979 plan is described in the attached figure. For comparative purposes, we have attempted to maintain the same operating tails assay as in the February plan whenever possible. As might be expected, fully powering the gaseous diffusion complex beginning in 1981 would result in an increased accumulation of enriched product inventory over that shown in our February plan. However, it should also be emphasized that the February plan is based on DOE obtaining firm power in accordance to our power contracts and that prospects of obtaining large amounts of reasonably priced power to fully power the plants would not be good even if it were desirable to increase near term production levels. Of course, the added production costs and associated inventory interest charges would result in a higher price of separative work than in the February plan.

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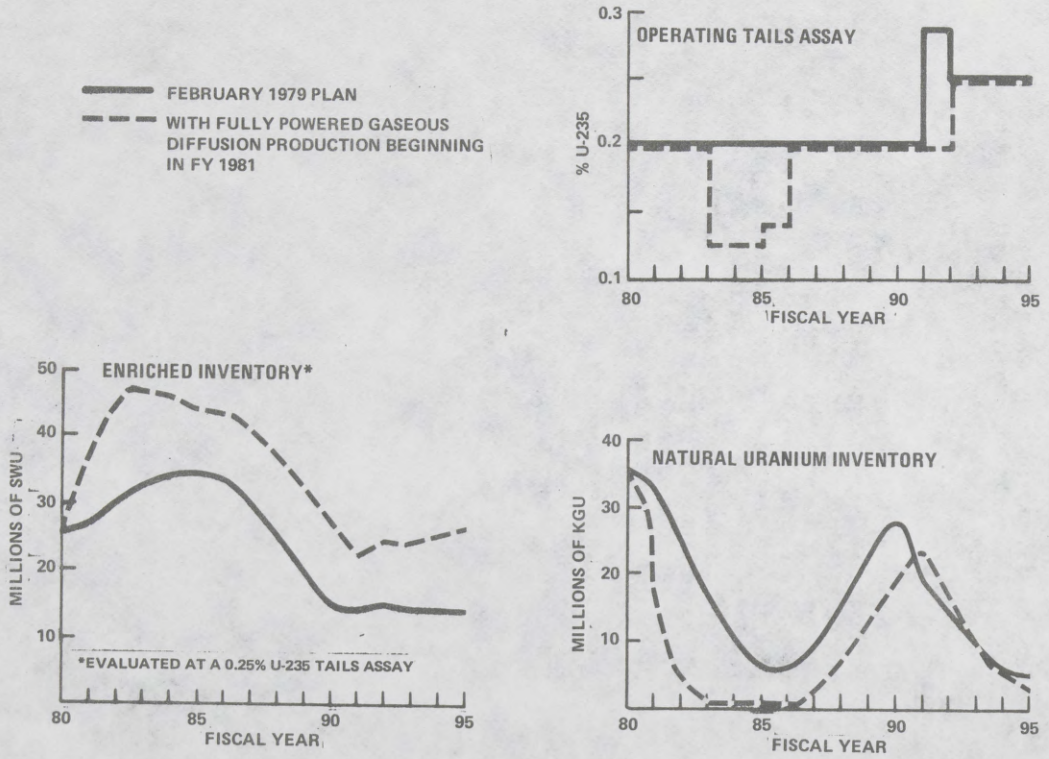
FIGURE 1


FEBRUARY 1979 PLAN
WITH FULLY POWERED GASEOUS DIFFUSION PRODUCTION BEGINNING IN FY 1981
OPERATING TAILS ASSAY
% U-235
0.3
0.2
0.1
80
85
90
95
FISCAL YEAR
ENRICHED INVENTORY*
MILLIONS OF SWU
50
40
30
20
10
*EVALUATED AT A 0.25% U-235 TAILS ASSAY
80
85
90
95
FISCAL YEAR
NATURAL URANIUM INVENTORY
MILLIONS OF KGU
40
30
20
10
80
85
90
95
FISCAL YEAR

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

8. If the recent 5.1% increase in electrical generation were to be sustained through 1990, what total electrical capacity would be required then? How does this compare with the Energy Information Administration forecast? What is the shortfall in electrical generating capacity under this scenario, versus the EIA forecast?

Answer:

If the peak demand grows at 5.1% through 1990, this demand would reach 757 GW versus 646 GW forecasted by EIA[1/] in its mid case projection, a difference of 111 GW. An aggregrate reserve margin[2/] of about 22% is considered reasonable for reliable service, and has been the apparent target of the ten year capacity/demand projections submitted annually to DOE by the reliability councils. The EIA mid case projected capacity of 879 GW would result in a reserve margin of about 16% comprised partially of retired gas and oil fired units. To increase the margin to 22% would require about an additional 45 GW of capacity.

1/ DOE/EIA - 0173/3, Annual Report to Congress, 1978, page 268, Table 16.4.

2/ Reserve, margin (%) = difference between net capacity and peak demand divided by peak demand, all multiplied by 100.

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Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

9. It was stated at the hearing that constructing an incremental unit of centrifuge enrichment capacity (about 1 MSWU) could be accomplished in 6 years, while nuclear power plants require from 8 to 12 years to bring on line. This time lag was stated as allowing the country the flexibility to provide adequate enrichment capacity on a dynamic basis. How many plant orders per year (worldwide) would you consider adequate to justify advancing the pace of the centrifuge plant construction schedule by 2 years i.e., the first, and all subsequent units coming on line 2 years earlier than is presently planned?

Answer:

Given the current status of the project, it doesn't appear that the initial increments of the Gas Centrifuge Enrichment Plant (GCEP) can be substantially accelerated from the present schedule. However, the completion date of the entire 8.8 million SWU GCEP capacity could be advanced by about two years after which additional capacity could be added at Portsmouth with a six-year construction lead time. By compressing the schedule in this manner, it appears that sufficient additional separative work could be produced to supply 6-8 GW/yr of new orders beyond our February 1979 expectations over the next 3-4 years. This increase could provide for new power plants to be on line between 1990 thru 1994, which were ordered by 1984. This also assumes that the added enrichment capacity necessary to sustain the additional power plants over the long term would be brought on as needed after completion of the 8.8 million SWU GCEP. It should be noted, however, that we are currently re-evaluating our nuclear power growth projections and it appears that there will be a further degradation in growth rather than the acceleration which would be needed to support advancing the pace of GCEP construction.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

10. In what ways is the Centrifuge Plant Demonstration Facility (CPDF) important to the development of industrial capacity? Will manufacturers of centrifuge machines be required to provide machines for this facility prior to production for the initial phase of the GCEP program? If not, why not? Where will the centrifuges modified to reflect last year's failure problems be tested?

Answer:

The CPDF is the first test of a production type unit cascade utilizing centrifuges and other cascade equipment and systems for the Gas Centrifuge Enrichment Plant (GCEP). Most of this equipment, including all the centrifuges, will be procured from industry. The CPDF will obtain information to show that producible centrifuge machines and the necessary industrial vendors are available, and that the cascade design, construction, and operation, and operation criteria are satisfactory for GCEP use.

The centrifuge manufacturers selected to participate in the Phase I program will produce the CPDF centrifuge machines prior to the initial centrifuge machine production for GCEP. The last CPDF centrifuge machine will be received in July 1982, and the first GCEP machine will be produced in August 1982.

The centrifuges modified to correct the quality control problems responsible for the machine failure experience last year are being tested in the Advanced Equipment Test Facility and will also be utilized in the Centrifuge Plant Demonstration Facility at Oak Ridge.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

11. How does the current program strategy assure that there will be ample competition for Phase II of the Portsmouth project? What is the estimate of the cost of Phase II? Is it possible that one of the three participants in Phase I may not be in a position to bid on Phase II, based on performance between now and then? Would carrying all competitive proposals through Phase I have been a more responsible policy?

Answer:

The current GCEP program strategy provides that the Phase II machine suppliers will be selected from the three Phase I suppliers. The estimated cost of Phase II centrifuge machine procurement is approximately $1.5 billion. While it is conceivable that one of the Phase I suppliers may not be in a position to bid on Phase II based on performance between now and the date of Phase II proposals, we have no reason to believe that this will be the case nor do we consider this sufficiently probable to warrant incurring the additional Phase I costs to retain a fourth supplier during Phase I. Additionally, competitive considerations are such as to induce even two suppliers to vie for Phase II contract benefits. We, therefore, do not believe that carrying four suppliers through Phase I would be a more responsible policy.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

12. When does DOE expect to have to make commitments to the last three increments of Portsmouth? What lead time is required for machine manufacturing? What manufacturing base is assumed? Has the Department explored opportunities for expanding private participation in these increments? With what results?

Answer:

The current overall GCEP schedule provides for having the first 2.2 MSWU of capacity completed and available in CY 1988, with commitments for additional increments of capacity being made approximately 7 1/2 years prior to the date when additional enrichment capacity is needed. We contemplate completion of the full 8.8 MSWU by 1993, and to meet this schedule it will be necessary to commit to increments 2, 3, and 4 in CY 81-82, CY 83-84, and CY 85-86 respectively. The foregoing is an assumed schedule and would necessarily need to be reviewed, in light of any changes to the projected demand for enriched uranium, before proceeding to build these additional GCEP increments.

The industrial centrifuge manufacturing base for the first 2.2 MSWU increment is projected to be adequate for subsequent increments with additional machine manufacturing capacity being supplied by these manufacturers. The lead time for additional machine manufacturing capacity is less than the build-cycle for each GCEP process building, and is therefore, not controlling in the construction of additional increments of GCEP capacity. Thus, at this time, expanded private participation is not believed necessary. Obviously, should the growth of nuclear power accelerate very substantially, this position would need to be reviewed.

Questions based on testimony of Dr. Stanley I. Weiss and William R. Voigt before the Subcommittee on Energy Research and Production on September 22, 1979.

13. Does DOE use any economic analysis other than perceived restrictions in budget authority to guide its enrichment program decisions? What, for example, are the estimated costs of the DOE-imposed delay in the schedule? At what point in its decision process does DOE consider additional costs to the consumer?

Answer:

DOE uses various economic analysis methods to evaluate uranium enrichment program plans and major capital projects; e.g.

- o comparison of net present value (discounted cash flow) to the Government of alternatives
- o benefit/cost analysis
- o total costs to our customers of enriched uranium
- o comparison of the discounted costs of producing enriched uranium
- o impact of alternatives on cost of production and selling price, and
- o payback period analysis

The selection of an operating plan and specific projects to be used as the basis for the budget request relies heavily on these economic analyses, but also considers other intangible or irreducible factors such as overall administration policy, budget constraints, as well as health, safety and national security considerations.

The delay in completion of the Gas Centrifuge Enrichment Plant from 1988 to 1993 increased the project's total estimated cost (TEC) by about $250 million in FY 80 dollars. However, it was our assessment that this increase in the TEC was justified by the avoidance of unnecessarily early capital expenditures and excessive accumulation of low enriched uranium inventory. The impact on our customers, and hence the consumer, is generally considered in the initial phases of developing uranium enrichment program plans and budgets.

Mr. McCormack. Our next witness is Dr. J. Robert Merriman, who is director of the Enrichment Technology Division of Union Carbide Corp., Nuclear Division, here at Oak Ridge. With Dr. Merriman is Mr. Paul Vanstrum. Is it your desire, gentlemen, that you both testify and then have questions, the two of you together, or would you prefer to have questions one at a time?

Dr. Merriman. However you desire.

Mr. McCormack. If you are testifying as a team, we can easily take the testimony from both of you, if you wish. We have your testimony before us and we will, without objection, insert your entire testimony in the record at this point, and you may proceed as you wish.

Do you wish to proceed first, Dr. Merriman?

[The prepared statement of Dr. Robert Merriman follows:]

Statement of
Robert Merriman
Director, Enrichment Technology Division
Union Carbide Corporation, Nuclear Division
Before the Committee on Science and Technology
Subcommittee on Energy Research and Production
U. S. House of Representatives
September 22, 1979
at
Oak Ridge, Tennessee

ADVANCED URANIUM ENRICHMENT TECHNOLOGIES

Mr. Chairman and Members of the Committee: I am pleased to have the opportunity to appear before this Committee today to discuss advanced uranium enrichment technologies.

URANIUM ENRICHMENT

In the Department of Energy's Advanced Isotope Separation (AIS) program, three technologies are currently being emphasized. I will naturally be focusing most of my remarks on these three concepts. Before discussing any details of these technologies, however, I would like to provide some background on uranium enrichment and Union Carbide's role in this field to indicate the basis of our perspective on today's advanced technologies.

Union Carbide has been involved with large-scale isotope separation since its beginnings in the Manhattan Project. We have had programs in uranium isotope separation process research and development since that time and have had major assignments in developing and deploying the gaseous diffusion process and in developing and demonstrating the gas centrifuge process which is now in the deployment phase. Union Carbide has also had research and development experience with other separation methods for uranium and other isotopes, such as aerodynamic processes, chemical exchange, molecular distillation, and sweep diffusion. In addition, we have operated production-scale thermal diffusion hardware, as well as the electromagnetic separation plant here in Oak Ridge using the CALUTRON separator. We have supported these technologies with extensive programs in materials science to learn how to handle both uranium metal and uranium hexafluoride in large-scale production systems.

Based on this broad background in separation science and materials technology, Union Carbide has been a participant in the current advanced isotope separation process development effort since the early days of the present DOE program. We have projects in support of all three of the current AIS processes, and we work closely with the other organizations involved in the AIS program. In addition, our experience through the years in uranium enrichment process assessment, engineering, demonstration, deployment, and operation has led to a role as DOE's evaluator of enrichment technologies. We do not have any institutional bias for or against

any particular process. Rather, our interest is in the United States' uranium enrichment program as a whole to assure that our nation has available to it the best set of uranium enrichment technologies to meet our energy production goals and to maintain a world leadership position in uranium enrichment. Since 1943, Union Carbide has been involved in looking at several hundred isotope separation processes or process proposals, and the goal has always been the same -- to find out which process is the best one for the country to use at any time and then urge and help with its implementation.

Characteristics of Isotope Separation Processes

To give you an understanding of how we look at isotope separation processes, I would like to describe some general characteristics of enrichment technologies. Every isotope separation technique has many features, some of which are listed in my first chart (Chart 1). The important point is that no single feature is decisive for any one application. Different combinations of technical and economic characteristics become important in meeting a given objective; still other combinations are important in meeting some other objective. That is, the most desirable combination of characteristics may be different, depending upon whether we want an economically competitive process for large-scale use in the production of slightly enriched uranium for nuclear power reactors or one for producing a small amount of highly enriched uranium for a few weapons. Further, the combinations may be added up differently by different countries, considering their own situations. Thus, the evaluation of an enrichment process requires an understanding not of single bits of information, but of many process characteristics and knowledge of end-use requirements, together with an understanding of the basic theory involved and key cost factors. Other points I have not explicitly covered in this chart, such as safety and environmental concerns, are also of great importance.

The three advanced isotope separation technologies we are working on hardest today all appear at this point to possess characteristics which combine to make them attractive for large-scale use within the light water reactor (LWR) fuel cycle (Chart 2). They all show the potential for low production cost, compared with gaseous diffusion and gas centrifuge, based on what we know today. In general, all three technologies have the potential for high separation factor, substantial throughput, low inventory, low energy consumption, low capital cost, and low operating cost. This overall set of characteristics distinguishes these AIS technologies from diffusion and centrifuge, and this is the basis for our strong interest in these concepts and the justification for our R&D program. The steps we need to take to pursue these potential advantages will be a central part of my remarks today.

While the three technologies being worked on today on a significant scale within the AIS program are frequently referred to as the "Advanced Processes", I think it would be incorrect to assume that these three concepts represent a closed and timeless set of good uranium enrichment

ideas. One has only to consider the short history of these processes -- 5 to 10 years -- to realize the importance of staying alert to new developments in this field.

With this background, I would now like to discuss three aspects of the current DOE AIS program on uranium enrichment. These are (1) a description of the three processes and their status, (2) the potential benefits to the U.S. of having a low-cost uranium enrichment process, and (3) the steps involved as we seek to exploit the potential of AIS to our advantage. I will try to indicate the incentives we see, the problems we face, and the path ahead.

CURRENT AIS TECHNOLOGIES

Of the three AIS technologies presently being developed within the DOE program, two are based on the use of lasers to effect the separation and are often referred to by the laser isotope separation (LIS) nametag (Chart 3). One LIS technology, being studied by C. Paul Robinson and his co-workers at the Los Alamos Scientific Laboratory (LASL) at Los Alamos, New Mexico, uses uranium hexafluoride (UF_6) as the process working fluid. Uranium hexafluoride is the same material used in the gaseous diffusion and gas centrifuge processes. Since uranium hexafluoride is a molecule, the technique being studied at Los Alamos is called Molecular Laser Isotope Separation (MLIS). The other laser isotope separation technology uses uranium metal vapor as its process material. It is being studied by James I. Davis and his colleagues at the Lawrence Livermore Laboratory (LLL) at Livermore, California. Since uranium metal vapor is a collection of uranium atoms, Livermore's process is called Atomic Vapor Laser Isotope Separation (AVLIS). The third advanced isotope separation process was invented by Professor John Dawson of UCLA and is based on the resonant addition of energy to a uranium plasma. This non-laser process is under study by Frank Ridolphi and his associates at the TRW Corporation, Redondo Beach, California. It is called the Plasma Separation Process (PSP).

I would now like to provide brief descriptions of how the advanced technologies separate uranium isotopes and statements of the present status of each process. These descriptions result from research on each technology aimed mainly at selecting concepts for the source, excitation, and extraction steps. That is, work has been mainly aimed at concepts for putting the process material (UF_6 or uranium metal) in the right form and at the right conditions for the process to occur (source), means for preferentially modifying the desired ^{235}U component of the process mixture (excitation), and methods for removing the modified ^{235}U component from the rest of the process mixture (extraction). Research and development on selection of materials for resistance to corrosion under extreme temperatures has also been important to each process. Additional technical detail on the fundamental bases for these processes is presented in Appendix A. The following discussions of the advanced processes outline how our present concepts might be reduced to practice.

Molecular Laser Isotope Separation (MLIS)

My next chart (Chart 4) shows schematically how the MLIS concepts might be applied in a process. First UF_6 is mixed with a carrier gas and expanded through a supersonic nozzle. In this expansion, the UF_6 is cooled to very low temperatures to put most of the molecules in the ground state where there are greater differences in isotopic features. At this point, the gas stream is irradiated with an infrared laser and some of the $^{235}UF_6$ molecules are selectively excited. This is followed by irradiation with an ultraviolet laser which removes a fluorine atom from the excited UF_6 molecules, converting them to UF_5. This process is called photodissociation. The solid UF_5 is then removed from the gas stream using something like a dust collector. The separated UF_5 can then be isolated and fluorinated to recover the enriched material as gaseous UF_6. Both the enriched product and depleted streams are routed through various cleanup and/or trapping devices.

My next chart (Chart 5) shows that the basic responsibility for the process science and definition and for the laser/electro-optical technology is at LASL, and we provide assistance in the spectroscopy, UF_6 technology, and materials science areas. Using the next chart (Chart 6), I would like to examine where the program stands. A little over 2 years ago, researchers at LASL succeeded in demonstrating that the MLIS approach was scientifically feasible for separating uranium isotopes. It was shown that a combination of infrared and ultraviolet photons could be used to selectively photodissociate UF_6 to UF_5 and that the isotopically enriched UF_5 could be removed from the process stream. A significant effort has been devoted to understanding the very complex nature of the interaction of infrared and ultraviolet radiation with UF_6 molecules. While a very impressive body of experimental and theoretical information has been developed in this area, there is not yet a full understanding of the physics of the process. Useful correlations have been made between the theory and experiments. In addition to the process science itself, a major and very important area of work within the MLIS program has involved the development of infrared and ultraviolet lasers. LASL has made good progress in this area, and there are now some lasers of the general type needed for the process. Additional lasers of a pre-prototype nature are now being procured from industrial sources. We have a large amount of work to do, however, to bring the infrared and ultraviolet laser systems up to the power levels and reliabilities needed for a production plant. One of the attractive advantages of the molecular process is the fact that it employs UF_6 as the process gas. Consequently, in the area of process equipment, such as gas compressors, nozzles, collectors, traps, etc., the technology that has been developed and proven in the gaseous diffusion program is of considerable value. It appears that most of the non-laser process hardware and systems that will be required for the MLIS process can be designed and fabricated using technology available from gaseous diffusion. Indeed, it is for this reason that much of the process development involving handling of UF_6 is being conducted at the Oak Ridge Gaseous Diffusion Plant.

I would like to conclude my discussion of the MLIS process by showing you some pictures of the devices presently being used in the Los Alamos and Oak Ridge laboratories:

Chart 7 Shows one of the ultraviolet laser concepts being developed at LASL.

Chart 8 is an interior view of the spectroscopy laboratory in the Oak Ridge GDP. This system, by the way, is built around a continuous UF_6 flow loop which has been in operation for 4 years and which utilizes a number of gaseous diffusion compressors which had previously been in standby.

Chart 9 shows a portion of LASL's continuous flow loop which will be used to study the process further using the pre-prototype lasers I mentioned a moment ago.

Atomic Vapor Laser Isotope Separation (AVLIS)

Turning now to the atomic vapor laser isotope separation approach, my next chart (Chart 10) shows schematically how the AVLIS principles might be applied in a process system. In AVLIS, the feed is uranium metal. This metal is melted in a vacuum chamber and a stream of uranium vapor flows from the liquid pool into a collection/extraction region. In the collection/extraction region, the atomic vapor stream is irradiated with laser photons in the visible region of the spectrum which selectively excite the ^{235}U atoms until they become ionized. The $^{235}U^{+}$ ions can be deflected to product plates, and the neutral ^{238}U atoms pass through the irradiation zone to a tails collector. Both the enriched product and depleted tails are then removed from the chamber.

As shown in my next chart (Chart 11), primary responsibility for development of AVLIS is at LLL, with Union Carbide having responsibility in the uranium handling technology and materials science areas. The current status of AVLIS is shown in my next chart (Chart 12). The scientific feasibility of the process was confirmed in macroscopic uranium enrichment experiments in 1975. The theory of AVLIS is fairly well understood. Two alternative laser candidates are under consideration. AVLIS requires lower power lasers than does MLIS. For this reason, the lasers required for an AVLIS production plant are closer at hand, although there is still a considerable amount of important engineering-type integration and control work that needs to be done. Much progress has been made in developing uranium vapor sources, and workable collector/extractor concepts have been identified. Prospects for satisfactorily resolving uranium handling and materials issues appear good, and the development program in this area builds on the technology base established within the weapons program. The major areas of concern at this time center on engineering the lasers and controls, further developing the collector, and pursuing the uranium handling issues.

My next few charts will illustrate some of the hardware being utilized in the AVLIS program:

Chart 13 shows a space frame at Livermore containing one of the laser types being considered. These lasers were purchased from an industrial supplier and represent a possible production plant concept.

Chart 14 is a view of another laser test facility at Livermore.

Chart 15 is a photograph taken inside the uranium materials handling laboratory at the Oak Ridge Y-12 Plant.

Plasma Separation Process (PSP)

My next chart (Chart 16) shows schematically how the PSP technology might be employed in a process. The PSP concept is exploited in a vacuum chamber which is located inside the field of a superconducting magnet. Uranium is fed to one end of the chamber in the form of metal. From this feedstock, uranium atoms are vaporized and directed down the length of the device. Next, the uranium atoms, both ^{235}U and ^{238}U, are ionized to form the plasma. As the ions continue to travel through the device in a spiral path, energy is added selectively to the $^{235}U^+$ ions thus increasing their orbit diameter relative to those of the $^{235}U^+$ ions. At the other end of the machine, the higher energy $^{235}U^+$ ions are collected separately from the $^{238}U^+$ ions.

As outlined in my next chart (Chart 17), primary responsibility for development of PSP is at TRW, with Union Carbide again assisting in the uranium handling and materials science areas. The status of the PSP is shown in my next chart (Chart 18). Considerable progress has also been made on PSP, and concept feasibility has been confirmed with macroscopic collections in uranium enrichment experiments conducted in 1976. The physics of ionized gases in the plasma regime of PSP is complex, but is becoming better understood. A comprehensive process model has recently been developed, and there has been some experimental confirmation. Key technical issues are in the general areas of getting good utilization of the plasma, in preserving the discrimination between the $^{235}U^+$ and $^{238}U^+$ ions at the process conditions of interest in a production plant, and in the detailed definition of components, such as the feeder, ionizer, and collector. As with AVLIS, materials problems associated with the handling of uranium also present technology development challenges. The major advantage of PSP is that much of the critical PSP hardware, including the large superconducting magnets, is within current state-of-the-art.

The following charts are photographs of some of the systems being used within the PSP development program:

Chart 19 shows one of the superconducting magnets at TRW. This magnet was purchased from an industrial vendor.

Chart 20 shows the experimental configuration with traversing diagnostics.

Oak Ridge uranium materials handling facilities shown earlier in Chart 15 are also being used in the PSP effort.

Summary

In summary, each of the three AIS approaches has certain unique advantages, summarized in my next chart (Chart 21). With MLIS, the main advantage is its use of UF_6 and consequent exploitation of gaseous diffusion systems and materials technologies. The main advantage of AVLIS is the relatively low laser power required, which puts this part of the technology closer at hand. The central advantage of PSP, of course, is that much of its technology base rests in the magnet and plasma experience gained in large part in the fusion energy program.

Of the many processes that we have reviewed and evaluated over the last few decades, it appears, based on what we know today, that the three presently being studied intensively in the DOE AIS program have the greatest potential from the standpoint of the U.S. enrichment enterprise as of 1979. The processes, because of the selective nature of their isotope effects, combined with significant throughput, are fundamentally different from gaseous diffusion. As shown in my next chart (Chart 22), all three have demonstrated scientific feasibility and have made significant progress in defining the key scientific and technical parameters required to understand them. The programs for all three processes are providing a good foundation of basic research, and in the near future, we should be well into scale-up and engineering demonstration. Some good starts have been made in the area of component development, but very much technology development and engineering demonstration work remains.

I would next like to discuss the potential benefits of the AIS technologies to help quantify our interest in them. Following that, I would like to discuss some of the substantial challenges to be faced as we go through the always-difficult technology development and engineering demonstration phases.

POTENTIAL BENEFITS OF ADVANCED URANIUM ENRICHMENT TECHNOLOGIES

The most obvious reasons for pursuing advanced enrichment technologies are business reasons which stem from having the lowest cost process in the marketplace. These are summarized in my next chart (Chart 23). They include (1) enhanced competitive position for the U.S. enrichment program, (2) opportunity to conserve and extend uranium resources, (3) potential to reduce the energy expended in the isotope separation process, and (4) lowering the enrichment component of LWR fuel cost.

Besides business reasons, there are two other important benefits from pursuing advanced uranium enrichment technologies which I would like to mention. First, it will help us evaluate the options other nations may have if they happen to be pursuing a similar line of research and development. From a proliferation standpoint, this is particularly important

and, in fact, was a major reason why the U.S. resumed work on the gas centrifuge in 1958. Second, it will help us evaluate other uses of the technology which may be important in both the nuclear and nonnuclear fields.

It is useful from the business standpoint to look ahead and examine the implications and possible impacts of lower cost enrichment processess. To set the stage for these projections, it might be helpful to examine some basic features of enrichment.

Relationships Between Uranium Feed and Uranium Enrichment

As I discuss in more detail in Appendix B, the designer of an enrichment plant has a choice between the use of feed and the use of enrichment capacity, as measured in separative work units (SWU's) to achieve a given production target. The plant can be designed to use less feed and more SWU's or to use more feed and less SWU's for the same amount of product, as shown in my next chart (Chart 24). The index which tells us how much feed and how much enrichment are being used is the plant tails assay. This, in turn, is related to the fractional recovery of ^{235}U from the feed. If we use a lot of feed and little enrichment capacity, the tails assay is high, and we leave a larger fraction of the ^{235}U in the tails. If we use a little feed and a lot of enrichment capacity, the tails assay is low, and we leave a smaller fraction of the ^{235}U in the tails. The choice is usually made on economic grounds: it depends on the relative costs of feed and SWU's. For any combination of costs of normal uranium feed and uranium enrichment, there is an economic optimum for the tails assay from the enrichment plants. At today's prices, i.e., about \$90/SWU and \$120/kg U for normal assay UF_6, the economic optimum tails assay is about 0.20%, representing 77% recovery of the ^{235}U from the feed. Lowering the separative work cost makes it increasingly advantageous to recover more and more of the ^{235}U, extending the utilization of the normal uranium resource. For example, at \$30/SWU and the same normal feed cost mentioned above, the optimum assay calculates to be about 0.10%, corresponding to 89% recovery of the ^{235}U. This point is the basis for one of the most important potential beneficial uses of AIS; i.e., stripping the existing tails stockpile as well as future tails to levels below their typical current value of 0.20%.

Potential Impact of Lower Enrichment Costs

There are three basic questions which need to be considered in trying to evaluate the potential impact of lower enrichment costs:

"Just what will the cost per SWU be?"

"When can the lower cost technology be deployed?"

"What will the characteristics of the enrichment business be at that time, i.e., the demand, the mix and relative economics of enrichment technologies in place, the uranium supply picture, and the like?"

At this point, there is of course, much uncertainty about each of these issues. There is uncertainty in what the cost per SWU will be for an AIS technology. There is uncertainty about when we can deploy the processes. And we certainly cannot forecast the characteristics of the U.S. enrichment business in the 1990's with any precision. Because of these uncertainties, we have looked at a range of situations which might prevail so that we can develop as broad an understanding as possible of the consequences of lower SWU costs.

In my next chart (Chart 25), I have plotted total net benefits, discounted at 10% per year back to 1979, versus $/SWU for processes meshing into the U.S. enrichment picture beginning in the mid-1990's. The parameter used is the level of nuclear power, both domestic and foreign, which will be sustained by the U.S. enrichment complex in the year 2000. Three levels are shown: 200 GWe, 400 GWe, and 600 GWe. For each level, a band is given representing ranges on assumptions used in calculating the estimated benefits. More specifically, the benefit areas and relevant assumptions which were varied are as follows:

Resource Conservation. As described earlier, reducing the cost of separating uranium isotopes makes it economically feasible to do more stripping and thereby to recover a correspondingly greater fraction of the ^{235}U during the enrichment process. This translates to extended utilization of uranium ore.

If a lower cost enrichment process is deployed along with existing gaseous diffusion and gas centrifuge plants (primary enrichers), then the tails from the primary enrichers could be fed to the lower cost plant for further recovery of the ^{235}U. In addition, accumulated tails from prior enrichment plant operations could be processed. The value of the tails stripping benefit at any given $/SWU level depends on the operating tails assay of the primary enrichers, the average tails assay of the accumulated stockpile, and the level and cost of ore production from the mining industry.

At today's ore prices, the tails stripping benefits disappear at about $90 to $120/SWU, depending primarily upon the assay of tails available to the tails stripper. This is not surprising based on comments made earlier about the optimum tails assay.

Before leaving this point, I might note that by the mid-1990's, the accumulated tails stockpile from the gaseous diffusion and gas centrifuge plant operations may represent another uranium source equivalent to 150,000 tons of normal assay U_3O_8. This would add 15% to the currently proven U.S. ore reserves. If you happen to see the tails cylinders at the Oak Ridge Gaseous Diffusion Plant on your tour this afternoon, you will be looking at what could become one of our nation's largest "ore deposits".

Energy Conservation. It has already been noted that the energy requirements for the advanced isotope separation processes are expected to be substantially below the 2300 kWh/SWU required for gaseous diffusion. Thus, as is true with the gas centrifuge process, each AIS plant would represent an important energy conservation step in its own right compared with existing diffusion plants. If total unit production costs, including capital investment recovery, become low enough, they will utimately reach a point where they become less than the out-of-pocket operating cost, $60/SWU, for the diffusion plants. At this point, displacement of existing gaseous diffusion capacity with new capacity from the lower cost process could be justified on economic grounds. This would not only save the incremental operating cost difference but also avoid new electric power plant construction equivalent to whatever diffusion plant supplier capacity becomes available for other consumers.

Market Penetration. It has also been noted that the capital costs of plants using the advanced technologies may be much lower than those for gaseous diffusion and gas centrifuge plants. At the higher GWe levels, i.e., above about 325 GWe, there would be a need for new capacity beyond the gaseous diffusion-GCEP complex. The lower cost process would therefore penetrate the market above this level. In projecting these benefits, it was estimated that the competition would be with centrifuges ranging from GCEP-level costs down to those reflecting substantial improvements in centrifuge cost and performance.

Some of the conclusions which can be seen in the chart are that:

The benefits of deploying a lower cost enrichment process are a function of the level of nuclear power supported by the U.S. enrichment business; i.e., upon the deployment opportunities and level.

The benefits are also very dependent on the cost of separative work, vanishing completely once this exceeds $90 to $120/SWU.

The benefits are attractive even at low deployment levels (e.g., 200 GWe) providing the SWU cost is low enough. That is, a good low cost enrichment process is not totally dependent upon the aggressive utilization of nuclear power for its economic justification.

With regard to lower cost enrichment technologies, the economic issue is of more importance than the availability issue. That is, we do not need just another process to provide enriched uranium capacity -- we already have methods to do this. Our interest really comes if the low cost targets are realized.

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Based on evaluations we have recently made, taking into account what we know about the science of each technology and the problems which remain to be solved before they can be considered for large-scale use, we believe the potential of the three AIS processes is at the lower end of the $/SWU axis, shown on the chart. At this level, the estimated benefits could be substantial -- several billions of dollars. As I have emphasized, however, there is both uncertainty and much work remaining to be done. I would therefore like to discuss some of the things we need to do in the years ahead to pursue the potential of AIS.

ADVANCED ENRICHMENT TECHNOLOGY DEPLOYMENT CONSIDERATIONS

Over many decades of experience and in many different programs, engineers have learned that in the path from scientific feasibility, through development and demonstration, to deployment of a functioning and economically competitive technology, there are many steps to be taken, as shown in my next chart, (Chart 26). In the case of the DOE AIS program, these steps will take many years and require many millions of dollars. To justify this substantial commitment, we must avoid the situation in which a technology with a potential of low separative work cost ends up as one with a cost no better than processes already available. Therefore, the steps in the deployment path must be taken with care and without shortcut.

Deployment Phases

In discussing the deployment phases, it is convenient to use the categories I have listed on the chart. In the real world, however, within any given program, some elements might be in one phase and some in another phase. The categories serve to describe the status in a qualitative way and on an overall basis.

Scientific Research. The scientific research phase (Chart 27) tells us whether or not a credible process exists and gives us our first and most uncertain estimates of its economical potential. In the AIS program, we have now built a substantial science base, with particular attention to demonstration of scientific feasibility, identification of the important scientific parameters, development and validation of theories and process models, selection of process concepts, identification and/or invention of key hardware, collection of some data for component design and cost estimates, and estimation of economic potential. These data determine the direction the subsequent process development should take.

In the science phase, the facilities are typically laboratory systems and bench-scale devices, such as I showed in my earlier charts. The experiments are typically of small scale, with limited integration, and of relatively short duration.

Technology Development. Following the research phase is the technology development phase, (Chart 28), where we will be focusing more on scalable hardware concepts and system integration issues. Significant industrial participation will be initiated during this phase. The hardware will begin to look more like that which might ultimately be deployed in a production plant. There will, of course, be a substantial expansion of the process performance and cost data bases, as well as continued updating of economic projections.

In the technology development phase, experiments will include tests using integrated subscale process systems and run times which are a significant fraction of those required in a production plant.

Engineering Development and Demonstration. Following the technology development phase will be the engineering development and demonstration phase (Chart 29). It is here that the final data base for production plant design and economic potential will be determined. It is also during this phase that the important questions related to costs, systems integration, hardware lifetimes and reliability, maintainability, operability, and the like, will be answered. The industrial participation will be substantial during this phase.

During the engineering demonstration phase, experiments will be conducted with essentially full-scale, fully integrated systems, and run times will approximate those needed in the production plant.

In each phase of the program, we compare the predictions of process theory with experimental results and estimate process economics. The comparison of theory with experiment is necessary for the prediction of process performance; that is, to answer the question, "How many SWU's will it produce?". The estimation of costs is necessary to answer the question, "How much will the SWU's cost?". A statement of economic potential must fold together estimates of both performance and cost.

In addition, other issues, such as those involving safety, environmental protection, health, proliferation, and safeguards, will receive increasing attention as the program evolves through the different phases.

Following the engineering development phase, the last step in the deployment path would obviously be the design, construction, and operation of a production plant.

The entire program encompassed in this discussion is needed to convert our present view of the potential of the advanced isotope separation processes into a reality. We think now that the potential is there for advanced processes to be much less costly than gaseous diffusion or gas centrifuge. This gives us the incentive to move forward vigorously when we are ready so that the benefits can be obtained as early as possible. But we should not move ahead too soon or with poorly thought-out plans lest the benefits erode away because of premature technology choices or incomplete answers to technology problems. The best way to assure a

productive and cost effective program is continual evaluation of the economics and uncertainties during each program phase to substantiate the potential, combined with application of rigorous criteria which specify preconditions which must be met before a process is moved from one phase to the next.

Of course, you will recognize that the comments I have just made are not unique to the AIS program but really apply to most technologies being taken from the idea stage to the production stage. While this scenario is not original, it is useful in the AIS effort to help us gauge where we stand at any given point and what we have left to do.

With these comments as a background, I would like to review some elements of the path we see at present for development and deployment of the AIS technologies. We have accumulated a growing body of scientific information, as I have already mentioned, and are in a position to begin planning for the next major step, i.e., the technology development phase. The major efforts in the technology development phase will center on the design, construction, and operation of the so-called "Development Module". Such a system could come on-line in the mid-1980's. This will represent one of the most important steps in the entire AIS program, and I would like to discuss it in some detail.

The Development Modules

Current plans (Chart 30) for the AIS development modules call for them to:

> Provide integrated representations of the enrichment process concepts.
>
> Operate at rates which are the equivalent of tens of thousands of SWU/yr for short periods of time (hours or days).
>
> Operate for duty cycles which are sustained long enough to confirm the credibility of the process for a production application.

With these characteristics, the development module will really be serving three purposes. First and foremost, as the name implies, the development module will be the major test bed for the technology development phase I discussed earlier. Second, the development modules will play a pivotal role in the technology transfer from the laboratories to the engineering designers and developers. Third, it is inevitable that the development modules will be looked at for a demonstration of the readiness of the process for large-scale use.

On this latter point, I might mention practical problems which must be satisfactorily resolved before AIS can be considered ready for production use:

Predictability of Size/Performance Scaling. To be convincing, there will need to be evidence that the process scaling laws are known and are being followed, such that further scaling beyond the levels represented in the development modules can be reasonably assured.

Materials Availability. Not only will materials systems need to be validated over sufficient exposure times in true operational environments, but also viable fabrication routes must be identified.

Operational Control. There should be a good understanding of the staffing requirements for a production plant (number and level of expertise), the process instrumentation and control features, and the intrinsic system responses to upsets. There will need to be both demonstrated and analytical assurances of control.

Safety and Environmental Impact. The development module design and operation will provide excellent opportunities to conduct assessments of process safety, health physics, and industrial hygiene issues, as well as methods for controlling pollution.

Plant Conceptual Design. Even while the development modules are being used for tests, good conceptual designs of the production plant will be needed to establish the extent to which the development module characteristics are congruent with plant requirements.

Proliferation and Safeguards. In addition to providing further data on the proliferation-related aspects of the processes, the development modules can be used in the evaluation of initial safeguards concepts.

As I noted earlier, we believe the evaluation of the readiness of AIS during the development module testing will be very important. The objective of the development module project will be to satisfactorily resolve the problems I mentioned above and prove these solutions by successful operation for a convincing period. If this in fact proves to be the outcome, then we believe that a commitment could be made to go forward ultimately to a production plant. There, of course, would also have to be a commitment to support the corollary engineering demonstration and pilot plant activities which would be necessary along the way. The timing of the subsequent steps is, of course, much less clear than that for the development modules and will obviously depend to a high degree on the outcome of the development module effort.

CONCLUSION

The DOE Advanced Isotope Separation technology R&D program has been highly productive. Good progress has been made in important areas of all three of the current AIS technologies, MLIS, AVLIS, and PSP. Uranium has been enriched in laboratory systems using all three techniques. Process concepts have been identified, and some of the key process hardware is now under development. In addition, some laboratory versions of scalable components are being purchased and used in the programs. Materials and systems for containing and handling the process working fluids, e.g., uranium and UF_6, have also been identified. Based on program results to date we are certainly optimistic that the problems of developing a low-cost enrichment technology can be solved for one or more of the AIS technologies.

We have assessed the incentives for and consequences of introducing a much lower-cost uranium enrichment process into the U.S. enrichment picture. The potential economic and resource conservation benefits are attractive over a broad range of nuclear power utilization levels and enrichment business environments. However, we must first solve a number of practical problems lest the potential benefits remain just that. This will take several years and substantial funding. The key to maximizing our chances of realizing these benefits is a program guided in pace and direction by a continued assessment of the technology potential and of the costs to achieve that potential. Benefits will, of course, be realized more quickly if resources are applied commensurate with the increasing needs at each successive phase in the program and if they are allocated on the basis of progress and potential.

The present DOE AIS program plan calls for a process selection at the end of FY 1981, development module operation starting in the mid-1980's, pilot plant operations through the late 1980's and early 1990's, and a first production plant in the mid-1990's. Because both the AIS technologies and the enrichment business are dynamic, continual evaluations of this plan must be made to determine if alternative plans are more attractive. We believe that an important planning principle is to assure that technologies having the greatest potential are moved forward without undue delay.

It is too early at this stage to predict with any precision when deployment of an AIS technology might occur. What we do see clearly are the need and justification for the development module effort being planned for the mid-1980's. Design of the development module should proceed in the near future, as soon as the science base is available, assuming cost studies indicate that projected benefits justify costs. We believe the development module will be the most important "next step" in the AIS program. In addition to its very crucial process development and technology transfer functions, the development module will be the basis for evaluating the readiness of AIS as of the mid-1980 time frame. Without hard data acquired in a meaningful configuration at appreciable scale in a system with convincing operating times, we cannot be assured that

large scale process deployment can proceed with a high likelihood of success. The development module is the system which will give us that kind of data. For this reason, we strongly endorse the development module program.

Mr. Chairman, this completes my discussion of advanced uranium enrichment technologies. I would be pleased at this time to answer any questions.

APPENDIX A

FUNDAMENTAL BASES OF CURRENT AIS PROCESSES

Both of the laser processes, that is, both MLIS and AVLIS, make use of the fact that atoms and molecules absorb and give off energy in the form of photons, but only in discrete amounts of energy. That is, any given atom or molecule can exchange energy with its environment over a fairly broad range, not in a truly continuous fashion, but stepwise. There is a base energy content, called the ground level, and there are also various higher energy levels, called excited states. Each of these levels corresponds to a very specific mix of features, such as electron energies in an atom, vibrational energies of molecules, and molecular rotations. For example, we can take an atom or molecule in its ground state and add energy to it stepwise to raise it to an excited state, but only if the energy we add corresponds exactly to what is required to effect some discrete change, such as a particular increase in the electron energy of an atom or the vibrational energy of a molecule. By the same token, an atom or molecule in an excited state will decay to a lower energy state only by giving off specific amounts of energy, again corresponding to a discrete change within the atom or molecule. Chart A1 describes the electromagnetic spectrum in terms of the related properties of wavelength, frequency, and energy, and in terms of the associated atomic or molecular changes.

The idea in laser isotope separation (LIS) is to find an energy condition where there are differences between the features of the different isotopes which are far enough apart to permit selective excitation by a laser photon. The excitation, of course, must cause a change in the properties of the atom or molecule which allows its separation from the unexcited material.

MLIS. If we look now at the molecular LIS process and consider in some detail a UF_6 molecule, we find that such a molecule has six fundamental vibrational modes, as shown in Chart A2. Notice that in two of these vibrational modes, the uranium atom moves, whereas in the other four, the uranium atom is not involved. We, of course, are interested in the modes where the uranium moves, because the basis of the process is the fact that the frequency of vibration is slightly higher in the lighter $^{235}UF_6$ molecule than in the heavier $^{238}UF_6$. This gives us a different energy target for the $^{235}UF_6$ than for the $^{238}UF_6$, and we can preferentially excite the $^{235}UF_6$ to higher vibrational energy states using infrared photons that are precisely matched to these transitions. Thus, after the addition of infrared energy, we are left with $^{235}UF_6$ that is in a more excited state than the $^{238}UF_6$. Since an excited molecule behaves quite differently from an unexcited one, we then have some choices about how to capitalize on this difference. In the MLIS process, as indicated in Chart A3, we utilize the property that the probability of a UF_6 molecule absorbing a high energy ultraviolet photon increases as the molecule absorbs infrared photons. Chart A4 indicates very

schematically where the infrared and ultraviolet regions of interest are. The absorption of a high energy ultraviolet photon by an excited $^{235}UF_6$ molecule excites the molecule so much more that the molecule breaks apart to give $^{235}UF_5$ and a fluorine atom. UF_5 has far different physical and chemical properties than UF_6; in fact, at process conditions, UF_5 is a solid and UF_6 is a gas. Therefore, it then becomes a rather straightforward task to separate the enriched UF_5 from the depleted UF_6.

AVLIS. In the case of the atomic vapor LIS process, we are working with uranium atoms rather than UF_6 molecules. Because the nucleus of ^{235}U is lighter than that of ^{238}U, there are differences in electron orbit characteristics which, again, cause the ^{235}U to present a different energy target to photons than the ^{238}U. As indicated in Chart A5, using photons in the visible region of the spectrum, we can selectively excite the ^{235}U atom and, in fact, can add enough energy to cause an electron to be stripped from the atom. This gives us $^{235}U^+$ ions, that is, charged particles, mixed in with the neutral ^{238}U atoms which remain unexcited. Charged particles behave much differently than atoms, so the $^{235}U^+$ ions can be removed from the stream using electric and/or magnetic fields. Chart A6 shows the region in the electro-magnetic spectrum where uranium atoms absorb energy.

PSP. The Plasma Separation Process is based on the use of an electromagnetic field of a specific frequency, rather than laser light of a specific frequency, to excite an oscillation in a uranium plasma. A plasma is a mixture of charged particles, i.e., ions (positive charges) and electrons (negative charges). As shown in Chart A7, in a magnetically confined plasma there is an oscillatory mode that corresponds to circular motions of the plasma ions. The frequency with which an ion rotates in the fixed magnetic field, called the ion cyclotron frequency, depends upon the mass of the ion and is therefore different for $^{235}U^+$ ions than for $^{238}U^+$ ions. Thus energy can be added preferentially to the $^{235}U^+$ ions by matching the oscillations of the electromagnetic energy source with the $^{235}U^+$ ion cyclotron frequency. With the energy source in resonance with the $^{235}U^+$ ion motion, and thus off-resonance with the $^{238}U^+$ ion motion, the energy, velocity and circular orbit radius of the $^{235}U^+$ ions are selectively increased. This difference in energy and orbit radius between the $^{235}U^+$ and $^{238}U^+$ ions allows selective collection of the desired $^{235}U^+$ product.

APPENDIX B

SOME URANIUM ENRICHMENT PLANT CHARACTERISTICS

The production capacity of uranium enrichment plants is usually referred to in terms of separative work units (SWU's) rather than material quantities. The SWU is defined such that combination of both the weight and ^{235}U concentration of a given product can be represented unambiguously by a single value.

Interchange of Feed and Enrichment

A uranium enrichment plant operates by taking a feed stream and dividing it into two separate streams: a product stream enriched in ^{235}U and a tails stream depleted in ^{235}U. To a certain extent, uranium feed can be interchanged with uranium enrichment to provide a fixed quantity of product. For example, suppose we need 1 kg of uranium enriched to 3.0% ^{235}U to use as nuclear reactor fuel. This 1 kg of product can be provided any of several ways, as illustrated on Chart B1. Assume that the feed is normal UF_6 at \$120/kg U and that enrichment services cost \$100/SWU. Both prices are near today's market prices. If the enrichment plant is operated at 0.30% ^{235}U tails assay, then 6.57 kg U of feed and 3.42 SWU's will be needed to produce the 1 kg of 3.0% product. The total cost would be about \$1130. Suppose, on the other hand, the enrichment plant is operated at 0.20% ^{235}U tails assay; that is, suppose more of the ^{235}U is removed from the feed stream than in the previous example. In this case, less feed will be needed, 5.48 kg U, but more SWU's will be required, 4.31. The total cost of the 1 kg of product would be lower, about \$1090. In another example, suppose it was desired to take some depleted uranium, say at 0.25% ^{235}U, and use it to make normal assay material, 0.711% ^{235}U, by stripping still more of the ^{235}U out. To get 1 kg of 0.711% ^{235}U, it would take 2.14 SWU's if the tails were stripped down to 0.075% ^{235}U. At \$100/SWU, this would mean in effect that the cost would be \$214/kg U of normal assay material. This would not be economically attractive today, since normal feed can be purchased on the open market for \$120/kg U. To make this particular example of tails stripping economically competitive, an enrichment process would be needed which produced separative work at about half the cost of the current processes.

Optimum Tails Assay

The above examples illustrate the point that, for any combination of costs of normal uranium feed and uranium enrichment, there is an economic optimum for the tails assay from the enrichment plants. This is illustrated in Chart B2 for low values of separative work cost. For any given ore cost, lowering the separative work cost increases the economic incentive to recover more and more of the ^{235}U from the normal uranium feed, extending the utilization of the normal uranium resource. This point is the basis for one of the most important potential benefits of low-cost enrichment technologies; i.e., the so-called "Tails Stripping" benefit.

PRINCIPAL CHARACTERISTICS OF ISOTOPE SEPARATION PROCESSES

- SEPARATION FACTOR
- THROUGHPUT
- INVENTORY OR HOLDUP
- ENERGY REQUIREMENT
- CAPITAL COST
- OPERATING COST ELEMENTS (INCLUDING RELIABILITY)

IMPORTANCE OF COMBINATIONS DIFFERS, DEPENDING UPON APPLICATION

CHART 1

PRINCIPAL CHARACTERISTICS PROJECTED FOR CURRENT AIS TECHNOLOGIES

	GASEOUS DIFFUSION	GAS CENTRIFUGE	AIS POTENTIAL
SEPARATION FACTOR	LOW	MODERATE	HIGH
THROUGHPUT	HIGH	LOW	MODERATE
INVENTORY	MODERATE	LOW	LOW
ENERGY CONSUMPTION	HIGH	LOW	LOW
CAPITAL COST	HIGH	HIGH	LOW
OPERATING COST (OTHER THAN ENERGY)	LOW	MODERATE	LOW

CHART 2

THE CURRENT
DOE ADVANCED ISOTOPE SEPARATION TECHNOLOGY PROGRAM

TECHNOLOGY	PARTICIPANT–DATE	APPROXIMATE CUMULATIVE LEVEL OF EFFORT THROUGH FY 1979
MOLECULAR LASER ISOTOPE SEPARATION (MLIS)	LOS ALAMOS SCIENTIFIC LABORATORY (LASL) – 1971 UNION CARBIDE (UCCND) – 1973	$97 MILLION
ATOMIC VAPOR LASER ISOTOPE SEPARATION (AVLIS)	LAWRENCE LIVERMORE LABORATORY (LLL) – 1974 UCCND – 1974	$57 MILLION
PLASMA SEPARATION PROCESS (PSP)	TRW, INC – 1976 UCCND – 1977	$28 MILLION

CHART 3

THE MOLECULAR LASER ISOTOPE SEPARATION PROCESS

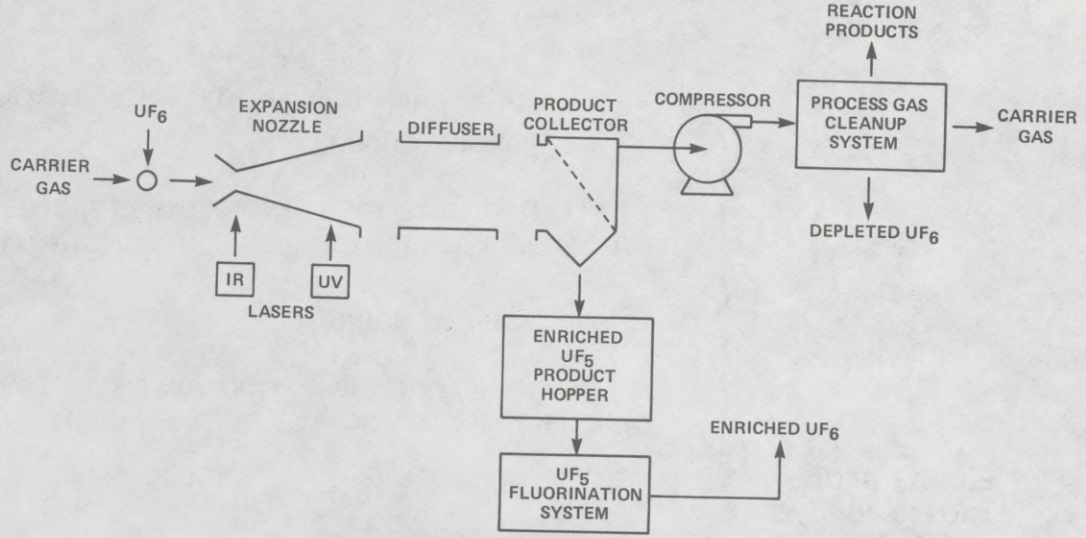


CHART 4

MOLECULAR LASER ISOTOPE SEPARATION PROGRAM PARTICIPANTS

LOS ALAMOS SCIENTIFIC LABORATORY

- PROCESS DEFINITION
- PROCESS SCIENCE
- LASER/ELECTRO-OPTICAL TECHNOLOGY

UNION CARBIDE CORPORATION, NUCLEAR DIVISION

- SPECTROSCOPY
- UF_6 TECHNOLOGY
- MATERIALS SCIENCE

CHART 5

STATUS OF THE MOLECULAR LASER ISOTOPE SEPARATION PROCESS

- SCIENTIFIC FEASIBILITY ESTABLISHED
- BASIC PHYSICS IS COMPLEX:
  - HAS BEEN MODELED THEORETICALLY
  - SOME EXPERIMENTAL VERIFICATION
- CANDIDATE PROCESS LASERS IDENTIFIED; SCALE-UP TO PLANT SIZE REQUIRES TECHNOLOGY DEVELOPMENT
- UF_6 PROCESS AND ENGINEERING IS IN-HAND; BASED ON GASEOUS DIFFUSION EXPERIENCE

CHART 6

54-835 O - 80 - 7

PROTOTYPE HIGH REPETITION RATE ULTRAVIOLET LASER AT LASL

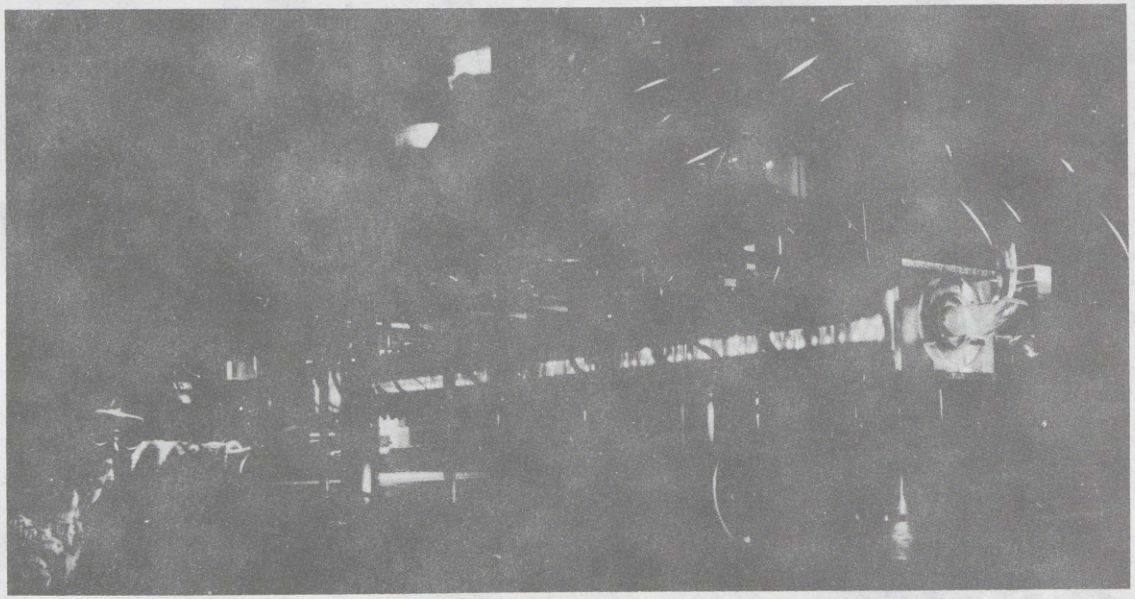


CHART 7

INTERIOR VIEW OF MOLECULAR LASER ISOTOPE SEPARATION LABORATORY AT ORGDP

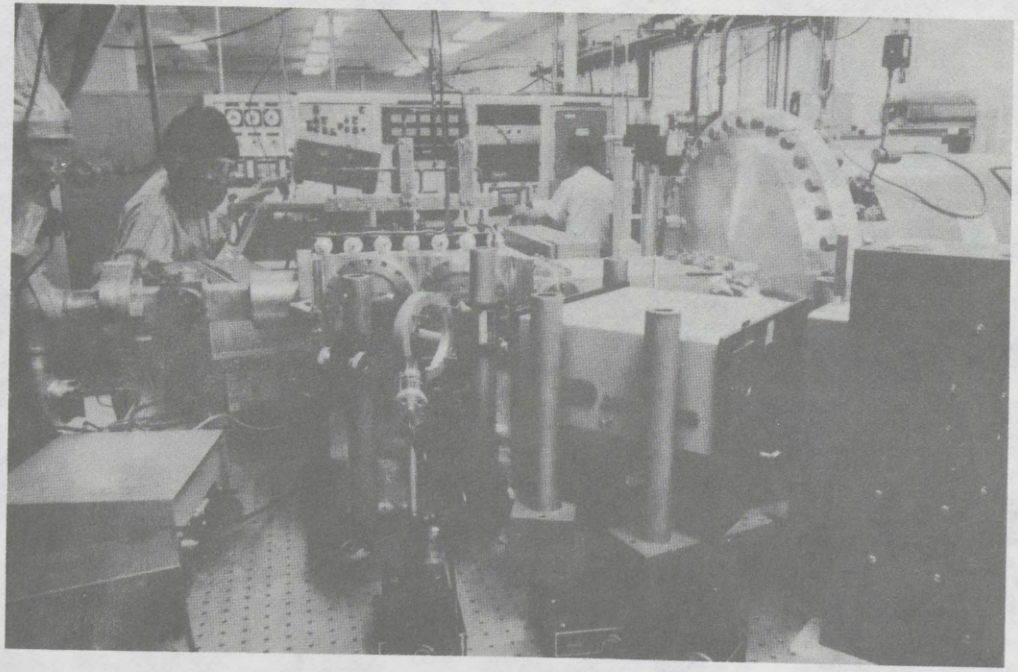


CHART 8

CONTINUOUS FLOW RECIRCULATING LOOP AT LASL



CHART 9

THE ATOMIC VAPOR LASER ISOTOPE SEPARATION PROCESS

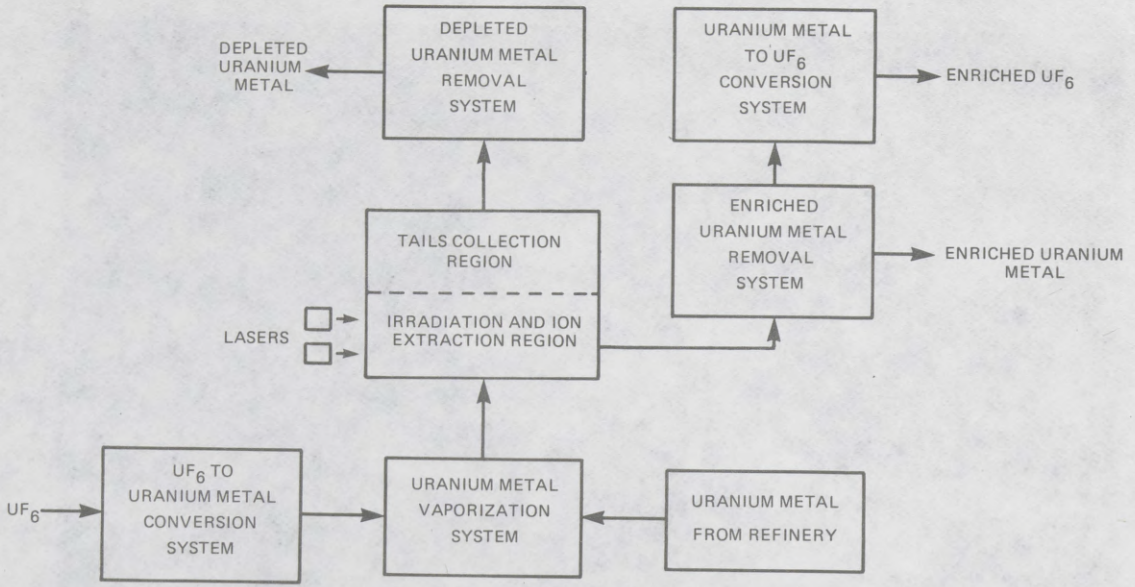


CHART 10

ATOMIC VAPOR LASER ISOTOPE SEPARATION PROGRAM PARTICIPANTS

LAWRENCE LIVERMORE LABORATORY

- PROCESS DEFINITION
- PROCESS SCIENCE
- LASER/ELECTRO-OPTICAL TECHNOLOGY

UNION CARBIDE CORPORATION, NUCLEAR DIVISION

- URANIUM HANDLING TECHNOLOGY
- MATERIALS SCIENCE

CHART 11

STATUS OF THE ATOMIC VAPOR LASER ISOTOPE SEPARATION PROCESS

- SCIENTIFIC FEASIBILITY ESTABLISHED
- PROCESS PHYSICS FAIRLY WELL UNDERSTOOD WITH SUBSTANTIAL EXPERIMENTAL VERIFICATION
- CANDIDATE PROCESS LASERS IDENTIFIED. POWER REQUIREMENTS MODERATE, FACILITATING SCALE-UP
- WORKABLE CONCEPTS IDENTIFIED FOR SOURCE, COLLECTOR, AND URANIUM HANDLING; TECHNOLOGY DEVELOPMENT REQUIRED
- URANIUM HANDLING TECHNOLOGY BUILDS ON WEAPONS PROGRAM DATA BASE

CHART 12

THE VENUS FACILITY – A MULTIPLE LASER ARRAY AT LLL

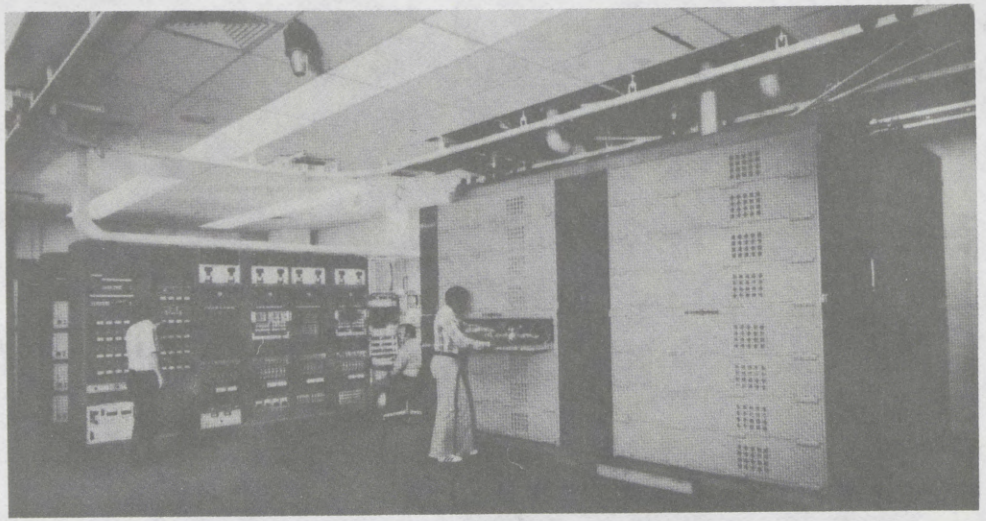


CHART 13

CLOSED CYCLE LASER TEST BED AT LLL

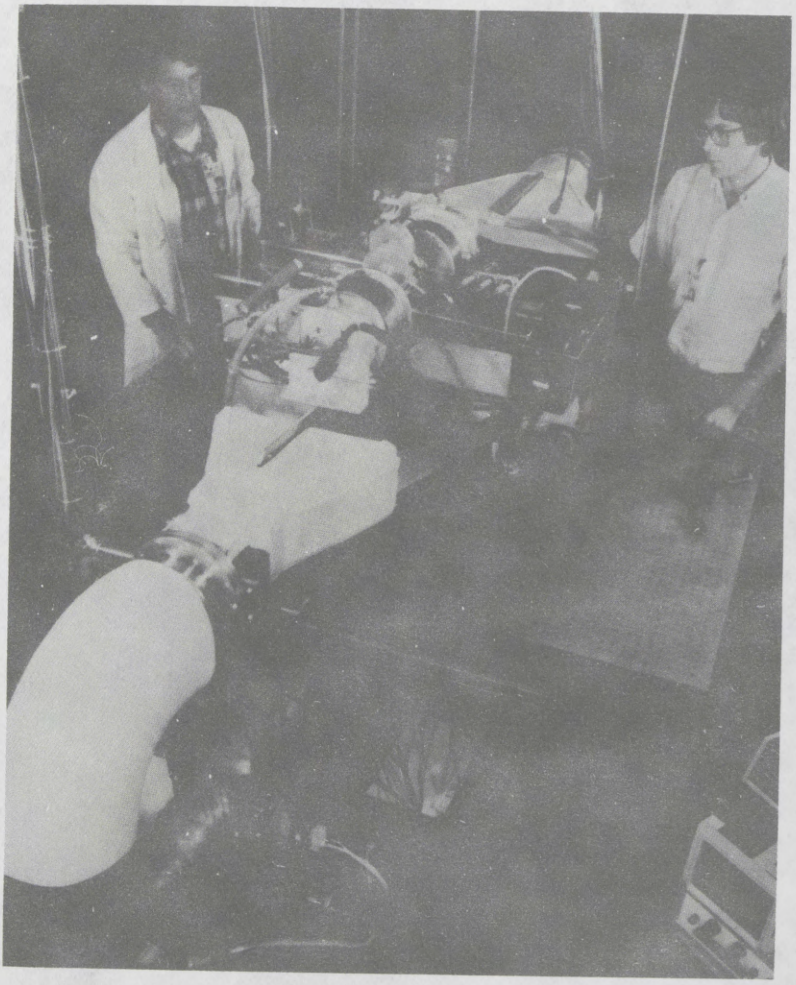


CHART 14

UCC-ND URANIUM HANDLING TECHNOLOGY LABORATORY AT THE OAK RIDGE Y-12 PLANT

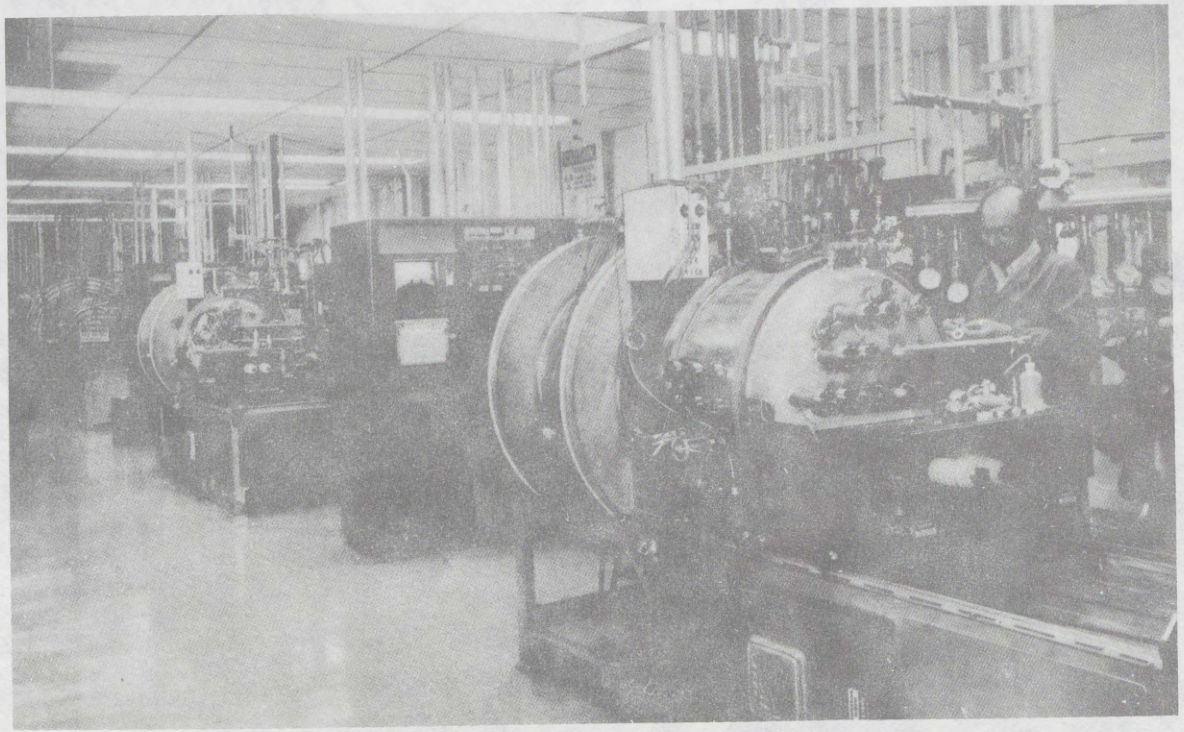


CHART 15

THE PLASMA SEPARATION PROCESS

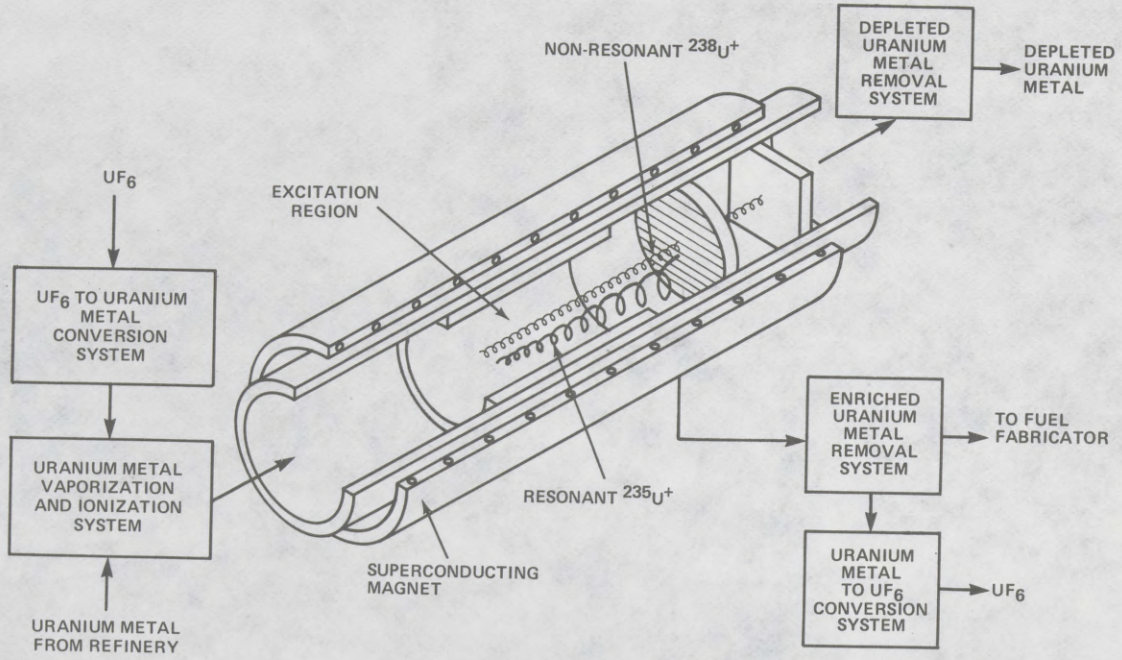


CHART 16

PLASMA SEPARATION PROCESS PROGRAM PARTICIPANTS

TRW, INC.

- PROCESS DEFINITION
- PROCESS SCIENCE
- PLASMA TECHNOLOGY

UNION CARBIDE CORPORATION, NUCLEAR DIVISION

- URANIUM HANDLING TECHNOLOGY
- MATERIALS SCIENCE

CHART 17

STATUS OF THE PLASMA SEPARATION PROCESS

- SCIENTIFIC FEASIBILITY ESTABLISHED
- BASIC PHYSICS IS COMPLEX:
  - HAS BEEN MODELED THEORETICALLY
  - SOME EXPERIMENTAL VERIFICATION
- EXPLOITS EXISTING SUPERCONDUCTING MAGNET TECHNOLOGY
- WORKABLE CONCEPTS IDENTIFIED FOR SOURCE, COLLECTOR, AND URANIUM HANDLING; TECHNOLOGY DEVELOPMENT REQUIRED
- URANIUM HANDLING TECHNOLOGY BUILDS ON WEAPONS PROGRAM DATA BASE

CHART 18

HALF METER MAGNET AT TRW, REDONDO BEACH, CA.

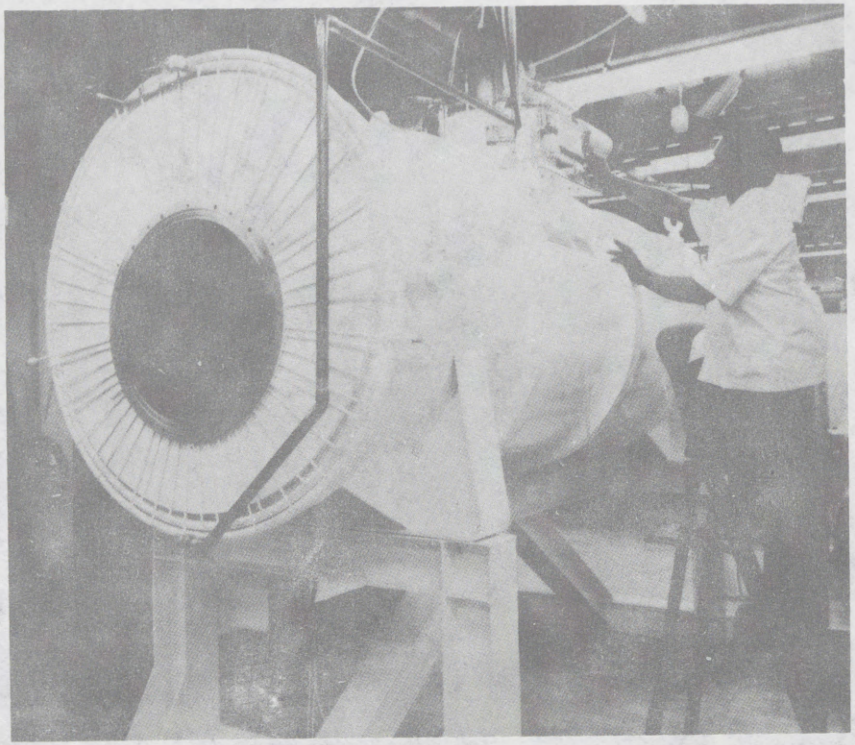


CHART 19

PLASMA SEPARATION DEVELOPMENT UNIT WITH TRAVERSING DIAGNOSTIC PACKAGE AT TRW, REDONDO BEACH, CA.

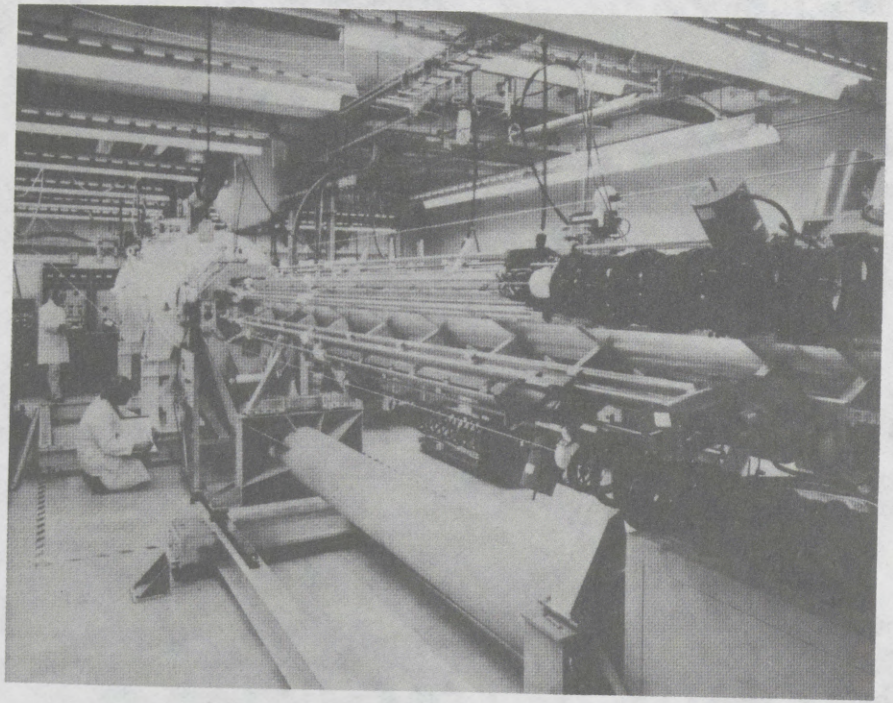


CHART 20

COMPARATIVE ADVANTAGES OF CURRENT AIS PROCESSES

MLIS	EXPLOITS EXISTING GASEOUS DIFFUSION UF_6 HARDWARE, SYSTEMS AND MATERIALS TECHNOLOGY
AVLIS	RELATIVELY LOW LASER POWER NEEDED
PSP	UTILIZES MAGNET AND PLASMA TECHNOLOGY FROM FUSION ENERGY PROGRAM

CHART 21

SUMMARY

- SCIENTIFIC FEASIBILITY HAS BEEN DEMONSTRATED FOR ALL THREE AIS TECHNOLOGIES
- GOOD BASIC RESEARCH FOUNDATION HAS BEEN ESTABLISHED
- RESULTS TO DATE ARE ENCOURAGING
- CONCEPTS HAVE BEEN IDENTIFIED FOR MOST PROCESS COMPONENTS. SOME TECHNOLOGY AND ENGINEERING DEVELOPMENT HAS BEEN INITIATED
- NEXT STEP INVOLVES CONCEPT AND TECHNOLOGY DEVELOPMENT, SCALE-UP AND INTEGRATION

CHART 22

54-835 O - 80 - 8

REASONS FOR INTEREST IN ADVANCED URANIUM ENRICHMENT PROCESSES

BUSINESS REASONS

- ENHANCE U.S.'s COMPETITIVE POSITION
- CONSERVE AND EXTEND URANIUM RESOURCES
- REDUCE ENERGY EXPENDED IN URANIUM ISOTOPE SEPARATION
- REDUCE COST OF ENRICHMENT COMPONENT OF LWR FUEL COST

TECHNOLOGICAL/POLICY REASONS

- EVALUATE OTHER USES
- UNDERSTAND OPTIONS OTHER NATIONS HAVE; E.G., IN PROLIFERATION

CHART 23

FEED AND ENRICHMENT REQUIRED TO MAKE 1 KILOGRAM OF 3.0% ENRICHED URANIUM AS A FUNCTION OF THE ENRICHMENT PLANT TAILS ASSAY

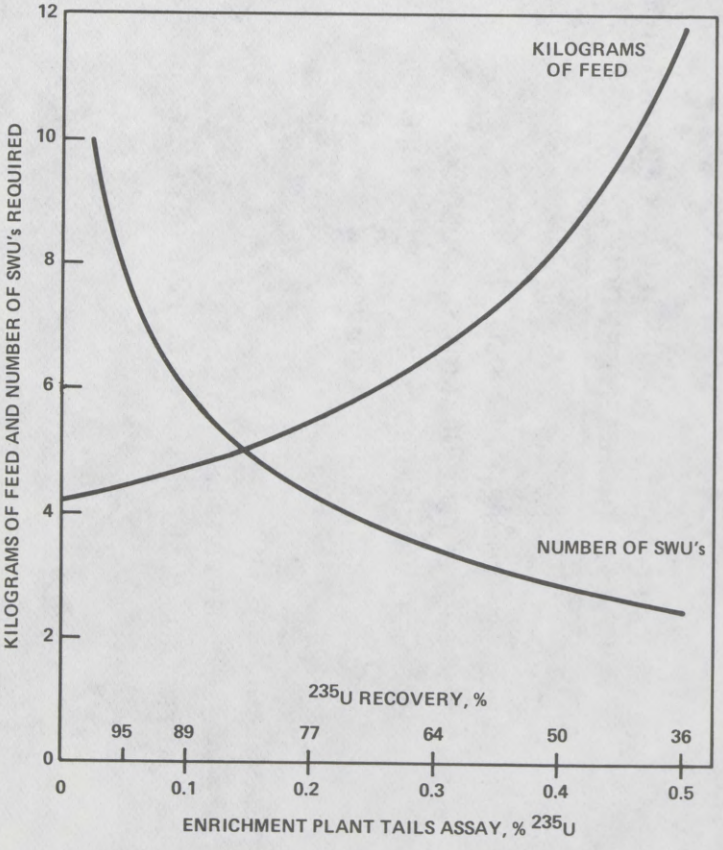


CHART 24

POTENTIAL ECONOMIC BENEFITS FROM THE DEPLOYMENT OF A NEW ENRICHMENT TECHNOLOGY AS A FUNCTION OF DEPLOYMENT LEVEL AND SEPARATIVE WORK COST

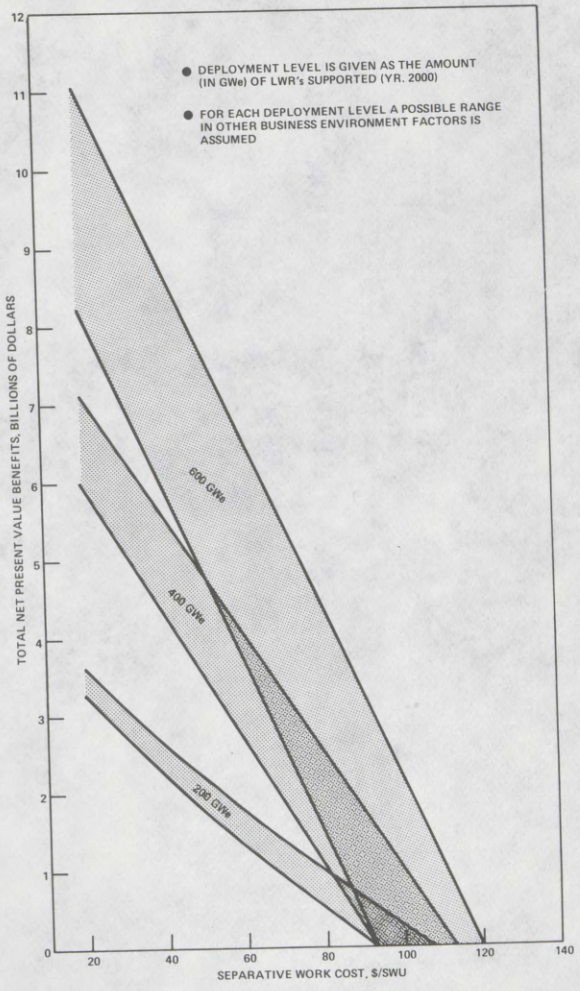


CHART 25

STEPS TO TECHNOLOGY DEPLOYMENT

- SCIENTIFIC RESEARCH
- TECHNOLOGY DEVELOPMENT
- ENGINEERING DEMONSTRATION
- DEPLOYMENT

CHART 26

THE SCIENTIFIC RESEARCH PHASE

ISSUES

- IDENTIFY RELEVANT SCIENTIFIC PRINCIPLES
- VALIDATE THEORIES AND MODELS WITH SMALL-SCALE EXPERIMENTS
- GENERATE PROCESS CONCEPTS
- IDENTIFY AND/OR INVENT KEY HARDWARE
- COLLECT DATA FOR COMPONENT DESIGN AND COST ESTIMATES
- ESTIMATE ECONOMIC POTENTIAL

TYPICAL FACILITIES

- LABORATORIES, BENCH-SCALE DEVICES

CHART 27

THE TECHNOLOGY DEVELOPMENT PHASE

ISSUES

- SPECIFY HARDWARE TAILORED TO PROCESS REQUIREMENTS
- INTEGRATE SUB SYSTEMS
- SCALE-UP COMPONENTS
- BEGIN STUDIES OF COMPONENT RELIABILITY, OPERABILITY, MAINTAINABILITY, ETC.
- COLLECT MORE DETAILED COMPONENT DESIGN AND COST DATA
- ESTIMATE ECONOMIC POTENTIAL
- INITIATE DEVELOPMENT OF INDUSTRIAL BASE

TYPICAL FACILITIES

- INTEGRATED SUBSCALE SYSTEMS

CHART 28

THE ENGINEERING DEVELOPMENT AND DEMONSTRATION PHASE

ISSUES

- VERIFY PERFORMANCE AT FULL SCALE
- ESTABLISH OPERABILITY, MAINTAINABILITY, PRODUCIBILITY, LIFETIME, AND RELIABILITY OF COMPONENTS AND SYSTEMS, INCLUDING AUXILIARIES
- PROVIDE DETAILED DESIGN PACKAGE FOR PRODUCTION PLANT
- CONFIRM ECONOMICS
- ESTABLISH INDUSTRIAL BASE

TYPICAL FACILITIES

- FULLY INTEGRATED, LARGE-SCALE SYSTEMS (PILOT PLANT)

CHART 29

AIS DEVELOPMENT MODULES

CRITERIA

- INTEGRATED ENRICHMENT SYSTEM
- APPRECIABLE CAPACITY (EQUIVALENT TO TENS OF THOUSANDS SWU/YR) FOR SHORT PERIODS OF TIME (HOURS OR DAYS)
- DUTY CYCLES LONG ENOUGH TO CONFIRM PROCESS CREDIBILITY

FUNCTIONS

- TEST BED FOR TECHNOLOGY DEVELOPMENT
- TECHNOLOGY TRANSFER
- DEMONSTRATION OF PROCESS READINESS FOR LARGE SCALE USE

CHART 30

THE ELECTROMAGNETIC SPECTRUM

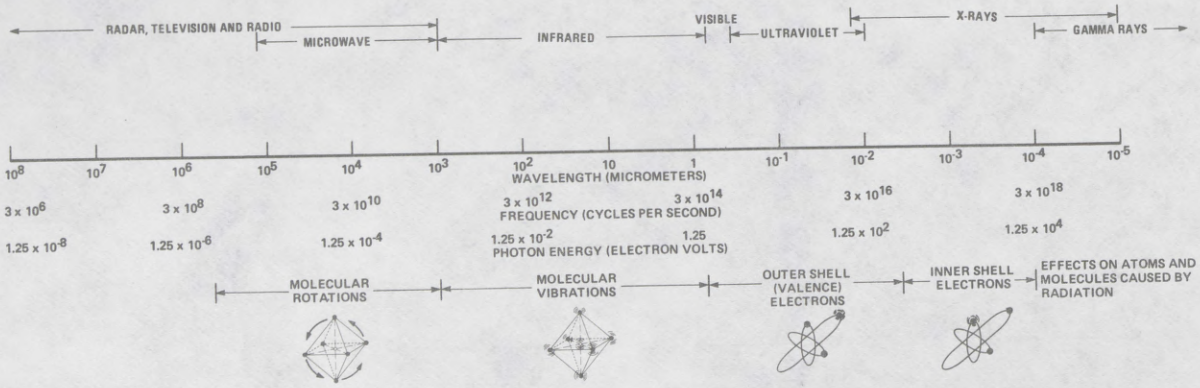
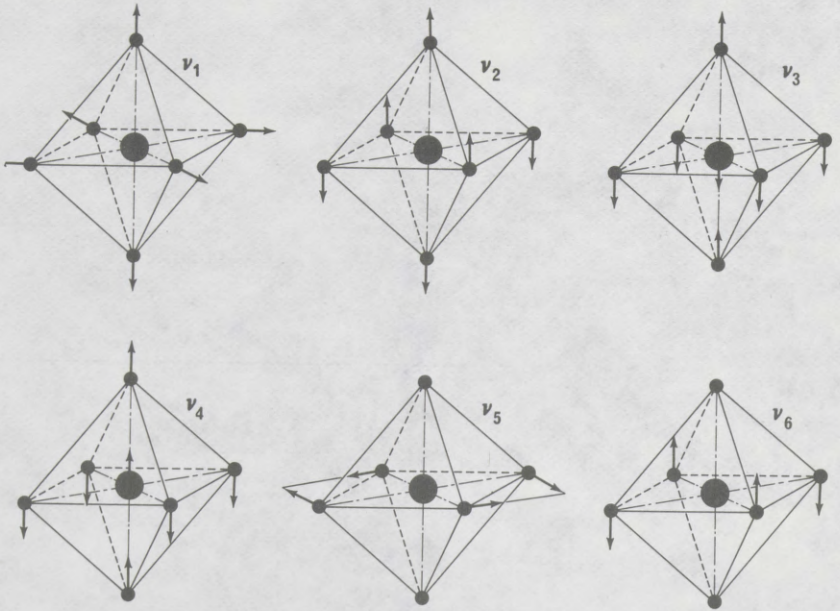


CHART A-1

UF_6 VIBRATIONAL MODES



● FLUORINE

● URANIUM

CHART A-2

ONLY ν_3 AND ν_4 ARE INFRARED ACTIVE.

ONLY ν_3 AND ν_4 SHOW A URANIUM ISOTOPE SHIFT.

BASIC PHYSICS OF MOLECULAR LASER ISOTOPE SEPARATION PROCESS

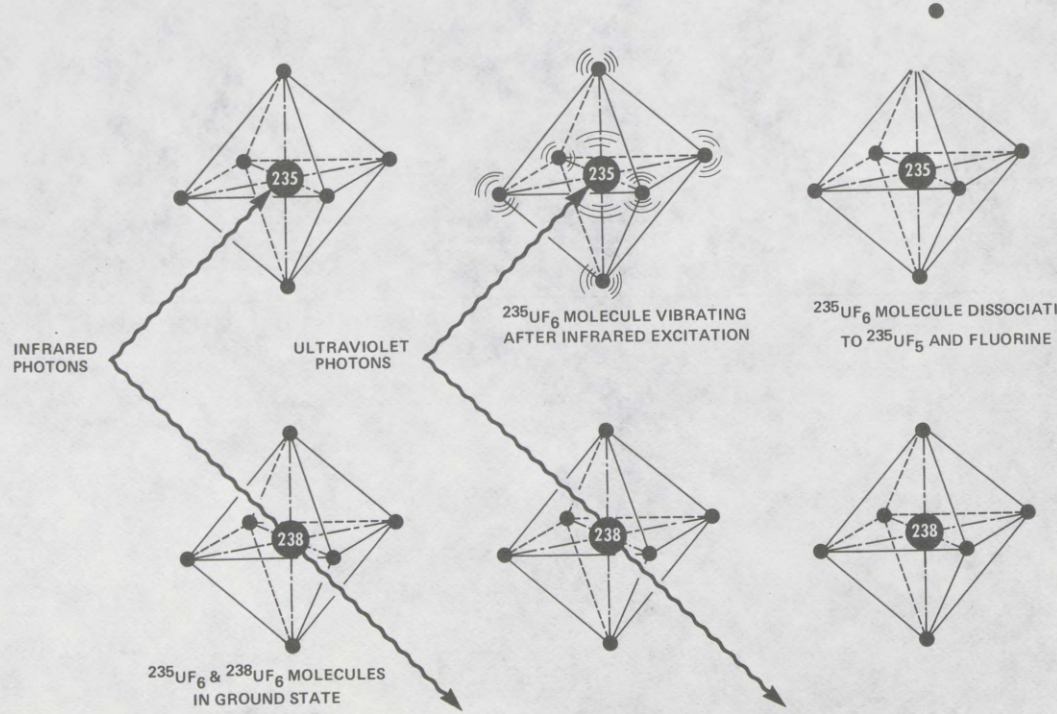


CHART A-3

ABSORPTION SPECTRA FOR UF_6

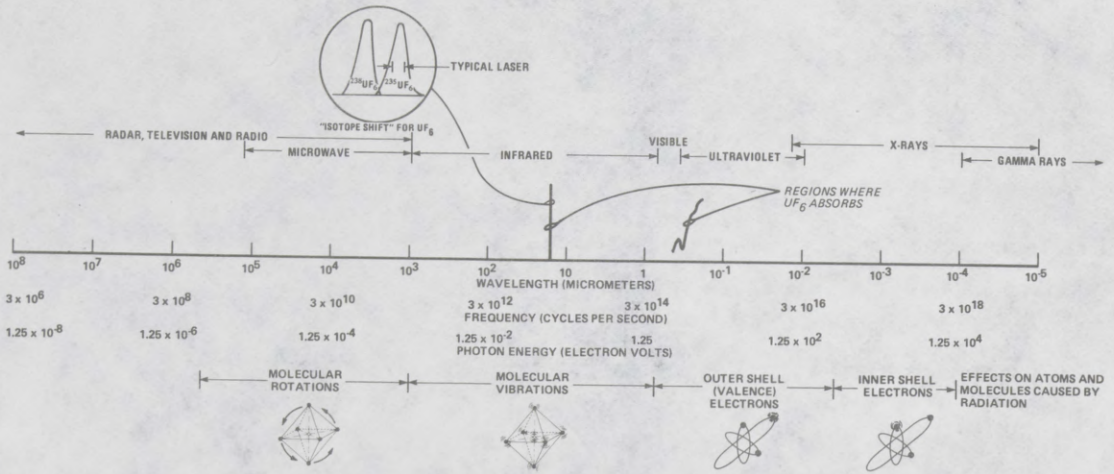


CHART A-4

BASIC PHYSICS OF ATOMIC VAPOR LASER ISOTOPE SEPARATION PROCESS

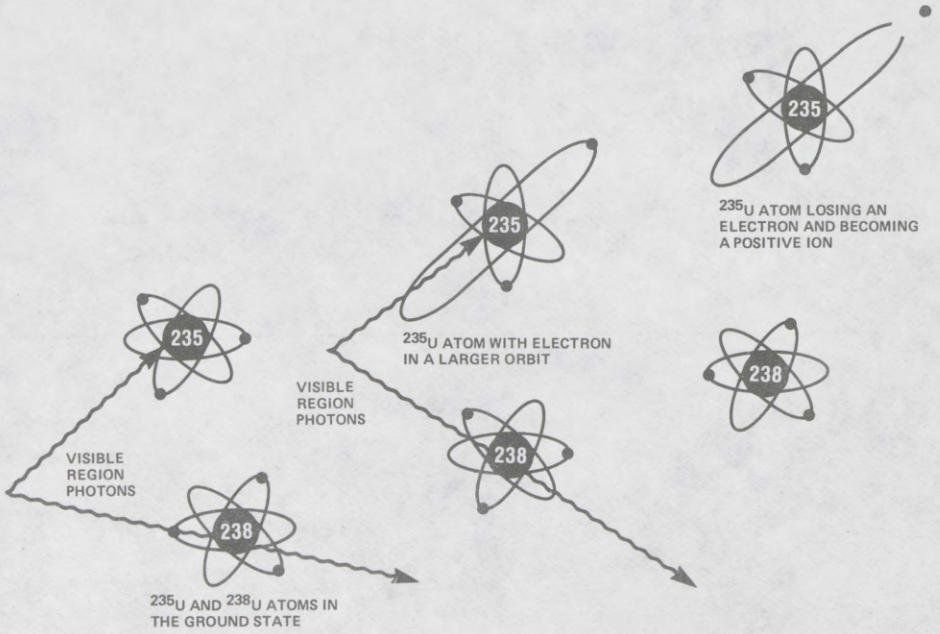


CHART A-5

ABSORPTION SPECTRA FOR URANIUM

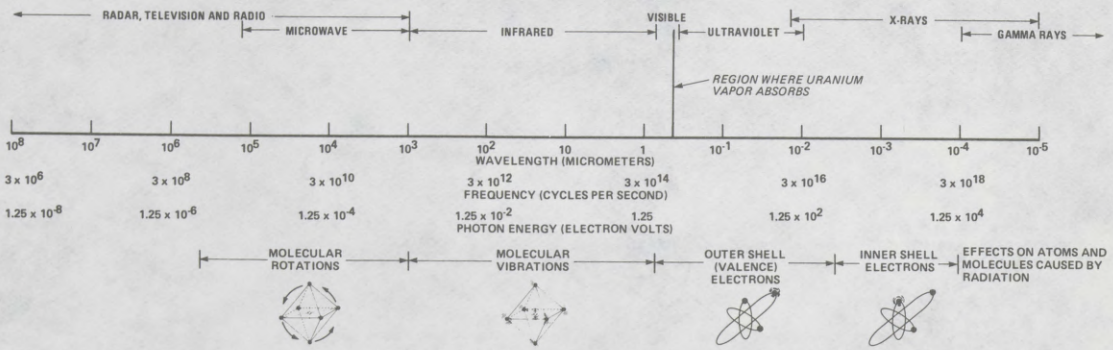


CHART A-6

BASIC PHYSICS OF PLASMA SEPARATION PROCESS

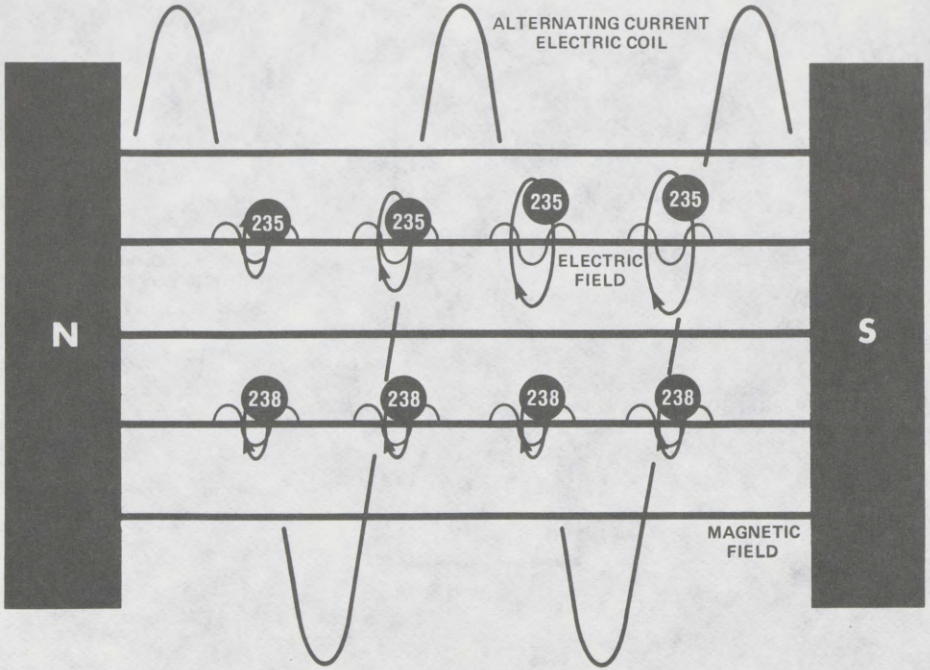


CHART A-7

SEPARATIVE WORK EXAMPLE

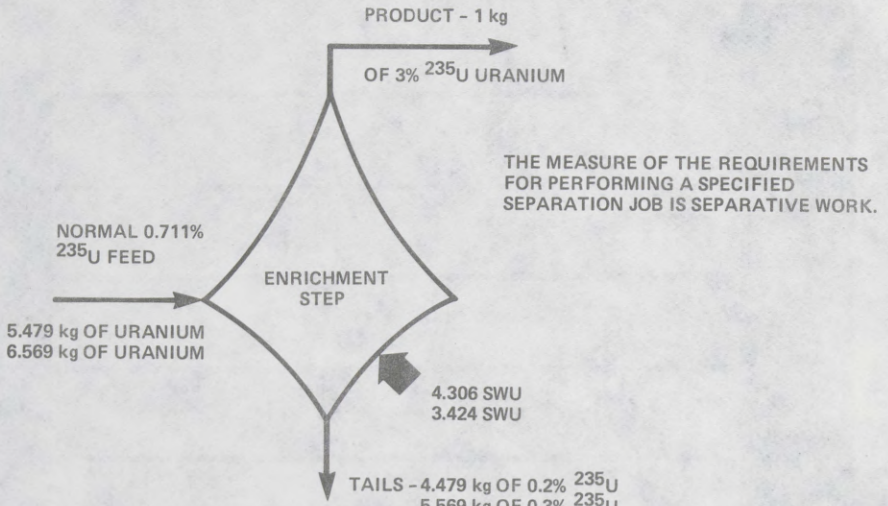


CHART B-1

54-835 O - 80 - 9

OPTIMUM ENRICHMENT PLANT TAILS ASSAY AS A FUNCTION OF THE COST OF FEED AND SEPARATIVE WORK

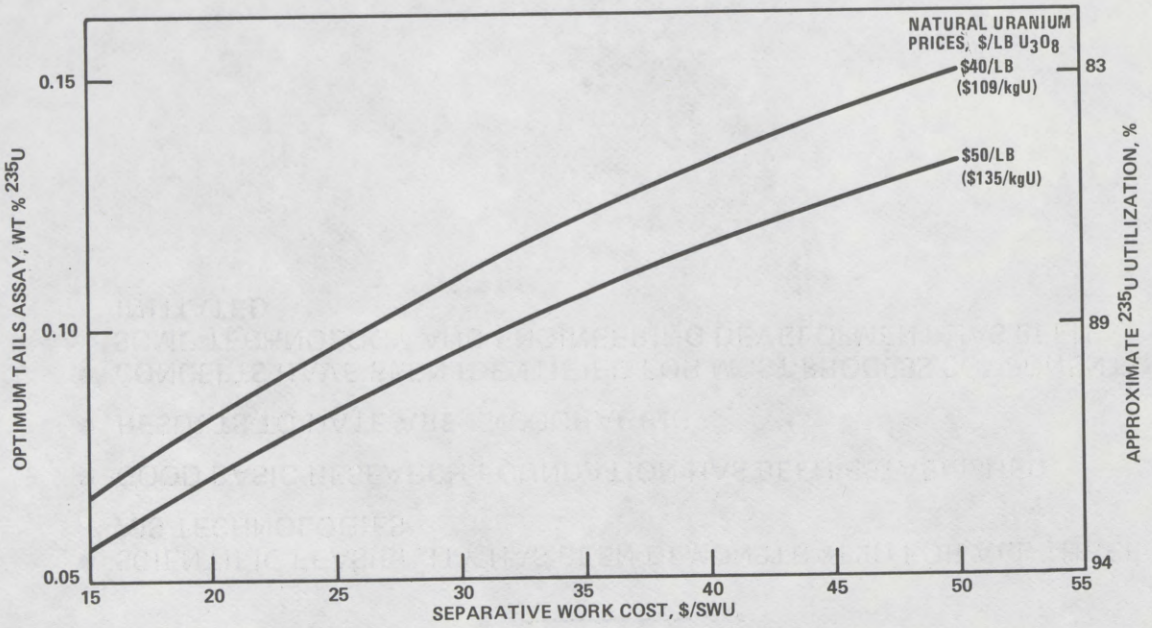


CHART B-2

SUMMARY

- SCIENTIFIC FEASIBILITY HAS BEEN DEMONSTRATED FOR ALL THREE AIS TECHNOLOGIES
- GOOD BASIC RESEARCH FOUNDATION HAS BEEN ESTABLISHED
- RESULTS TO DATE ARE ENCOURAGING
- CONCEPTS HAVE BEEN IDENTIFIED FOR MOST PROCESS COMPONENTS. SOME TECHNOLOGY AND ENGINEERING DEVELOPMENT HAS BEEN INITIATED

CHART X-4

SUMMARY (CONTINUED)

- POTENTIAL BENEFITS OF HAVING A MUCH LOWER COST URANIUM ENRICHMENT PROCESS ARE CONSIDERABLE
- A NUMBER OF PROBLEMS–REQUIRING SEVERAL YEARS AND SUBSTANTIAL FUNDING–MUST BE SOLVED TO CAPITALIZE ON THE POTENTIAL BENEFITS
- PROGRAM PACE AND DIRECTION SHOULD BE GUIDED BY:
  - CONTINUED ASSESSMENTS OF POTENTIAL AND COSTS TO ACHIEVE THAT POTENTIAL
  - ALLOCATION OF RESOURCES ON BASIS OF PROGRESS AND POTENTIAL
  - MOVING THOSE TECHNOLOGIES HAVING THE GREATEST POTENTIAL FORWARD WITHOUT UNDUE DELAY

CHART X-5

SUMMARY (CONTINUED)

- NEXT STEP INVOLVES COMPONENT AND TECHNOLOGY DEVELOPMENT, SCALE-UP, AND INTEGRATION
- A DEVELOPMENT MODULE COULD BE IN OPERATION BY THE MID-1980's. THIS SUB-SCALE, INTEGRATED SYSTEM WILL PROVIDE THE ESSENTIAL BASE OF HARD PROCESS DATA REQUIRED TO ESTABLISH THE READINESS OF AIS AT THAT TIME FOR LARGE-SCALE USE

CHART X-6

STATEMENT OF DR. ROBERT MERRIMAN

Dr. MERRIMAN. Mr. Chairman, members of the committee, Congressman Duncan, I am very pleased to have the opportunity to appear before you today and discuss the advanced uranium enrichment technologies. Without question, this is a very exciting field which I think has the potential of being of real benefit to the United States. I might say that advanced technology has always been a key factor in U.S. leadership in uranium enrichment. In the 1950's, the 1960's, and the 1970's, advances in gaseous diffusion technology paved the way for cost-effective capacity expansions. In the 1960's and 1970's, the gas centrifuge made great strides and has established its competitive position and, as you well know, has been selected for our next production plant. Now, in the 1970's, we are seeing some very different and very promising technologies emerging for which we now have very great hopes. On down the road, there may very well be other good ideas which we can turn to our advantage. The technology advances have helped and will continue to help us keep our enrichment business competitive and reach other important objectives.

In the Department of Energy's Advanced Isotope Separation, or AIS program, three technologies are currently being emphasized. Based on a broad background in isotope separation and materials technology, Union Carbide, under contract to the U.S. Government, has been a participant in this program since its early days. We have projects in support of all three of the current AIS processes, and we work closely with the other organizations involved. At Union Carbide, we do not have any institutional bias for or against any particular process. Rather, our goal—and I might say it is the goal of many people who are devoting their entire careers to uranium enrichment—is the same as it has been for several years, to find out which process is the best, the best for this country to use, and then urge and help with its implementation.

Today, my remarks will focus on the technologies now being pursued within the DOE AIS program. In my prepared statement, as you have requested, I have provided descriptions of each of these processes in terms of its physics basis and status. In this summary, I would like to quickly outline the program, give you a feel of our current scale of operation, discuss the incentives we see for the development and demonstration of the advanced processes, mention the problems we face in capitalizing on their potential, and indicate something of the path ahead. I should note that my remarks, particularly those touching on technical details and process status, may in some instances appear vague. This is because the advanced enrichment technologies are highly classified, as well they should be in my opinion. Incidentally, Mr. Chairman, if you prefer to follow the paper copy of my charts rather than the ones that will be shown on the screen, I have pulled together, as has Mr. Vanstrum, a special package containing only the slides that I will be using in my oral statement. I believe this package is on your table.

Mr. MCCORMACK. Are these attached to the testimony?

Dr. MERRIMAN. No, Mr. Chairman, there is a separate compilation there of the specific Vu-Graphs I will be using in my oral comments.

May I have the first slide please? [Chart 3 was displayed.]

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Of the three AIS technologies presently being developed within the DOE program, two are based on the use of lasers to effect the separation and are often referred to using the laser isotope separation nametag. One laser isotope separation technology, being studied by Paul Robinson and his coworkers at the Los Alamos Scientific Laboratory, Los Alamos, N. Mex., uses uranium hexaflouride, or UF_6, as the process working fluid. UF_6 is the same material we use in the gaseous diffusion and gas centrifuge processes. Since uranium hexaflouride is a molecule, the technique being studied at Los Alamos is called molecular laser isotope separation. The other laser isotope separation technology uses uranium metal vapor as its process material. It is being studied by Jim Davis and his colleagues at the Lawrence Livermore Laboratory in Livermore, Calif. Since uranium metal vapor is a collection of uranium atoms, Livermore's process is called atomic vapor laser isotope separation. The third advanced isotope separation process was invented by Prof. John Dawson of UCLA and is based on the resonant addition of energy to a uranium plasma. This process is under study by Frank Ridolphi and his associates at the TRW Corp., Redondo Beach, Calif. It is called the plasma separation process. And as I have said, and indicated on this chart, in Oak Ridge, we do work on supporting each of the technologies, in addition to assessments of their status and potential.

I would now like to show you some photographs taken within these laboratories to give you a feel for what some of the hardware looks like and to indicate the scale on which we are presently working.

First, with regard to molecular laser isotope separation my next chart: [Chart 8 was displayed.]

Is an interior view of the spectroscopy laboratory in the Oak Ridge Gaseous Diffusion Plant. This system, by the way, is built around a continuous UF_6 flow loop which has been in operation for 4 years and which utilizes a number of gaseous diffusion compressors which had previously been in standby. [Chart 9 was displayed.]

The next chart shows a portion of Los Alamos' continuous flow loop which they will use to study the process further using preprototype infrared and ultraviolet lasers which are currently being procured from commercial sources. [Chart 13 was displayed.]

With regard to the atomic vapor laser isotope separation process, my next chart shows a space frame at Livermore containing one of the two basic laser types that they are considering. These lasers were purchased from an industrial supplier and represent a possible production plant option. [Chart 15 was displayed.]

The next chart is a photograph taken inside the uranium materials handling laboratory at the Oak Ridge Y–12 plant where technology developed in the uranium foundry area as a part of the weapons program is being applied to the laser isotope separation program. [Chart 20 was displayed.]

With regard to the plasma separation process, my next chart shows one of the superconducting magnets at TRW. This magnet was purchased from an industrial vendor and is shown here in an experimental configuration with traversing diagnostics.

The chart that I just showed of the Oak Ridge uranium materials handling facilities also applies to the plasma separation process.

Of the many processes that we have reviewed and evaluated over the last few decades, it appears that based on what we know today,

the three presently being studied intensively in the DOE AIS program have the greatest potential. The processes, because of the selective nature of their isotope effects, combined with significant throughput, are fundamentally different from either gaseous diffusion or gas centrifuge, as shown in my next chart. [Chart 2 was displayed.]

In general, all three of these technologies have the potential for high separation factors, substantial throughput, low inventory or low in-process holdup, low energy consumption, low capital cost, and low operating cost. This overall set of characteristics distinguishes these technologies from diffusion and centrifuge. This is the basis, of course, for our strong interest in these concepts and the basis for their potential.

I would next like to discuss the benefits we might be able to obtain from the AIS technologies to help quantify our interest in them. Following that, I would like to discuss some of the substantial challenges to be faced as we go through the always difficult technology development and engineering demonstration phases.

There are three basic questions which I think need to be considered in trying to estimate the impact of lower enrichment costs:

First: Just what will the cost per separative work unit be?

Second: When can the lower cost technology be deployed?

Third: What will the characteristics of the enrichment business be at that point in time; that is, what will the demand be, what will be the mix and the relative economics of enrichment technologies in place, that is centrifuge and diffusion, what will the uranium supply picture look like, and so on?

At this point, there is, of course, much uncertainty about each of these questions. There is uncertainty in what the cost per separative work unit will be for an AIS technology. There is uncertainty about when we can deploy the processes, and we certainly cannot forecast the characteristics of the U.S. enrichment business in the 1990's with high precision. Because of these uncertainties, we have looked at a broad range of situations which might prevail so that we can develop as broad an understanding as possible of the consequences of lower separative work costs. [Chart 25 was displayed.]

In my next chart, I have plotted estimated total net benefits in billions of dollars versus enrichment costs, dollars per separative work unit, for processes meshing into the U.S. enrichment picture beginning in the mid–1990's. The parameter used for the three cases there is the level of nuclear power, both domestic and foreign, which will be sustained by the U.S. enrichment complex. The lower one is roughly 200 reactors, the middle one is roughly 400 reactors, and the upper one is roughly 600 reactors. For each of these levels, a band is given representing ranges on various assumptions used in calculating these estimated benefits. Specifically, some of the areas that we looked at were:

First: The benefits to be derived from being able to economically recover a greater fraction of uranium-235 from the normal feed in the enrichment process. This benefit, sometimes called "tails stripping", is an important resource conservation benefit.

Second: We have looked at benefits arising from some day, if the cost per separative work unit is low enough, being able to displace existing gaseous diffusion capacity with a new process which uses much less electric energy. This, of course, as has already been noted, would be an important energy conservation benefit.

Third: We have included estimates of benefits resulting from being able to penetrate the market at some level with a less expensive process. This would reduce in particular the large capital outlays needed for other processes.

Some of the conclusions which can be seen in this chart are:

First: The benefits of deploying a lower cost enrichment process are a function of the level of nuclear power supported by the enrichment business; that is, upon the deployment opportunities and the level of those opportunities.

Second: The benefits are, of course, very dependent on the cost of separative work achieved, vanishing completely once this exceeds $90 to $120 per separative work unit.

Third: The benefits are attractive at low deployment levels, provided the separative work costs are low enough. That is, a good low cost enrichment process is not totally dependent upon the aggressive utilization of nuclear power for its economic justification.

With regard to lower cost enrichment technologies, I believe the economic issue is of more importance in this particular case than the availability issue. That is, we do not need to invest many years and many dollars in developing just another process to provide enriched uranium capacity—we already have good methods available to do that today. Our interest really comes if these low-cost targets—the lower end of that scale—are ultimately achieved.

Now based on evaluations we have recently made, taking into account what we know about the science of each technology and the problems which remain to be solved before they can be considered for large-scale use, we believe the potential of the AIS technologies is at the lower end of the dollar per separative work unit axis I have shown here. At this level, the estimated benefits are very substantial, several billions of dollars. I would now like to discuss some of the things we should do in the years ahead to pursue these ideas and realize these benefits.

[Chart 26 was displayed.]

Over many decades of experience and in many different programs, engineers have learned that in the path from scientific feasibility, through development and demonstration, to deployment of a functioning and economically competitive technology, there are many steps to be taken, as shown in my next chart. In the case of the DOE AIS program, these steps will take many years and require many millions of dollars. As I mentioned a moment ago, we must avoid the situation in which a technology with a potential of low separative work cost ends up as one with a cost no better than the ones already available to us today. Therefore, I believe the steps in this deployment path must be taken with care and without shortcut.

In general terms, I would characterize the work ahead of us for the next 5 years or so as technology development, or the second stage in the chart. [Chart 28 was displayed.]

In the technology development stage, as indicated on my next chart, we will be focusing more on hardware that we can scale up and on system integration issues. Significant industrial participation will be initiated and/or expanded during this phase. The hardware will begin to look more like that which might ultimately be deployed in a production plant. There will, of course, be a substantial expansion

of the process performance and cost data bases, as well as continued updating of economic benefit projections.

In this technology development phase, experiments will include tests utilizing integrated—that is, all elements of the processes represented in the same system—subscale—that is, not yet at a production scale—systems and will employ run times which are a significant fraction of those required in a production plant.

The major efforts in the AIS technology development phase will center on the design, construction, and operation of the so-called "Development Module". Such a system could come on line in the mid-1980's. This will represent one of the most important steps in the entire AIS program, and I would like to discuss it next in a little more detail. [Chart 30 was displayed.]

Current plans, as shown in my next chart, for the AIS development modules call for them to: provide integrated representations of the enrichment process concepts: operate at rates which are the equivalent of tens of thousands of separative work units per year for short periods of time—that is, hours or days—and; operate for duty cycles which are sustained long enough to confirm the credibility of the process for production consideration.

With these characteristics, the development modules will really be serving three purposes. First and foremost, as the name implies, the development modules will be the major test beds for the technology development phase I have just discussed. Second, the development modules will play a pivotal role in the technology transfer from the laboratories to the engineering designers and developers. Third, it is inevitable that the development modules will be looked at for a demonstration of the readiness of the processes for large-scale use.

In this regard, there will be great attention to testing and proving solutions to problems in the areas of predictability of size and performance scaling, materials availability, operational control, safety and environmental impact, and the congruence between the technology that is available and the technology that must be available for a large-scale plant. These problems must be satisfactorily resolved before AIS can be considered ready for production use. If all this is, in fact, accomplished in the development modules, then we believe that a commitment could be made at that point to go forward to a production plant. There, of course, would have to be a commitment to support the corollary engineering demonstration and pilot plant activities which would also be both substantial and necessary along the way in order to verify economics, reliability, and so forth. The timing and duration of the subsequent steps are, of course, much less clear than that for the development modules and will obviously depend to a high degree on the outcome of the development module effort.

The DOE AIS technology R. & D. program, I think, has been a highly productive one.

As shown in my next chart, good progress has been made in important areas of all three of the current AIS technologies, molecular laser isotope separation, atomic vapor laser isotope separation, and the plasma separation process. Uranium has been enriched in laboratory systems using all three techniques. Process concepts have been

identified, and some of the key process hardware is now under development. In addition, some laboratory versions of scalable components are being purchased and used in the programs. Materials and systems for containing and handling the process working fluids—that is, uranium and uranium hexafloride—have also been identified. Based on program results to date, we are certainly optimistic that the problems of developing a low-cost enrichment technology can be solved for one or more of the AIS technologies.

As indicated in my next chart, we have assessed the incentives for and consequences of introducing a much lower cost enrichment process into the U.S. enrichment picture. The potential economic and resource conservation benefits are attractive over a broad range of nuclear power utilization levels and enrichment business environments. However, we must first solve a number of practical problems lest the potential benefits remain just that. This will take several years and substantial funding. The key to maximizing our chances of realizing these benefits is a program guided in pace and direction by continued assessments of the technology potential and of the costs to achieve that potential. Benefits will, of course, be realized more quickly if resources are applied commensurate with the increasing needs at each successive phase in the program and if they are allocated on the basis of progress and potential.

The present DOE AIS program plan calls for a process selection at the end of fiscal year 1981, deve'opment module operation starting in the mid-1980's, pilot plant operations through the late 1980's and early 1990's, and a first production plant in the mid-1990's. Because both the AIS technologies and the enrichment business are dynamic, continual evaluations of this plan must be made to determine if alternative plans are more attractive. We believe that an important planning principle is to assure that technologies having the greatest potential are moved forward without undue delay.

It is too early at this stage to predict with precision just when deployment of an AIS technology might occur.

However, as shown in my final chart, we do see clearly the need and justification for the development module effort being planned for the mid-1980's. The design of the development modules should proceed in the near future. We believe the development modules will be the most important of the various so-called next steps in the AIS program. In addition to other important functions the development modules will be the basis for evaluating the readiness of AIS as of the mid-1980 timeframe. Without hard data acquired in a meaningful configuration at appreciable scale in a system with convincing operating times, we cannot be assured that large-scale process deployment can proceed with a high likelihood of success. The development module is the system which will give us that kind of hard data, and thus maximize our chances of realizing an enormous potential benefit from the program. For this reason, we strongly recommend the development module program. We believe it merits aggressive support.

Mr. Chairman, this completes my segment of the discussion of the advanced uranium enrichment technologies.

Mr. McCormack. Thank you, Dr. Merriman. Mr. Vanstrum, do you wish to go ahead and make your presentation at this time?

Mr. VANSTRUM. That will be fine.

Mr. MCCORMACK. Thank you.

Mr. VANSTRUM. Mr. Chairman, members of the committee, Congressman Duncan, I am pleased to have been invited by the committee to testify this morning as part of your hearing on advanced uranium enrichment technologies. We are all especially pleased that the committee decided to hold their hearings here in Oak Ridge.

I have submitted a written statement to the committee in which I addressed, as you asked, the areas of uranium enrichment technology assessment, proliferation and safeguards, and issues and concerns that the country must deal with in trying to implement these new technologies. I would like to summarize some of the points in my written statement which presents views on what should be done in this important area of our technology from the perspective of someone who has worked in this area for about 35 years.

Mr. MCCORMACK. Mr. Vanstrum, without objection your entire testimony will be inserted at this point in the record. You may proceed as you wish.

[The prepared statement of Mr. Paul Vanstrum follows:]

Statement of
Paul R. Vanstrum
Vice-President, Engineering and Development
Union Carbide Corporation - Nuclear Division
Before the Committee on Science and Technology
Subcommittee on Energy Research and Production
U. S. House of Representatives
September 22, 1979
at
Oak Ridge, Tennessee

ISSUES AND CONCERNS IN URANIUM ENRICHMENT

INTRODUCTION

Mr. Chairman and members of the Committee, I am pleased to have the opportunity to discuss some of the issues of advanced processes for uranium enrichment. Some of the technical background of the U.S. advanced enrichment program has just been presented. I would now like to indicate, from my point of view, how these processes fit into the overall enrichment picture vis-a-vis the currently developed diffusion process, the planned centrifuge facility and other processes being studied and developed around the world.

We are hearing many questions these days about uranium enrichment, such as those dealing with supply and projected demand, choice of the best of several alternative processes, cost and pricing questions, strategies of plant deployment and operations, and questions about foreign competition. Issues of national policy are also being raised, such as identifying the U.S. objectives in uranium enrichment, how best to develop U.S. credibility as a reliable supplier, and the relationship of enrichment processes to nuclear proliferation goals, safeguards, and balance-of-trade.

I would like to offer my perspective on some of these issues and concerns in the uranium enrichment field. I have been privileged to work throughout my professional career in the uranium enrichment field and have been personally involved in many facets of enrichment -- process research, development, evaluation, selection, demonstration, deployment, and facility operation. I have also wrestled with the many other tough issues relevant to this field, including proliferation and safeguards. It is my belief that uranium enrichment is a great asset to this country as we consider the various ways to meet our energy objectives -- an asset which presents us with both opportunities and challenges.

What I would like to do is describe the enrichment scene and some of its dynamics and possible directions. To provide some background, I will start with a very brief historical review, but I want to concentrate primarily on the points of interest to you; namely, the current outlook for, and implications of, advanced enrichment technologies in the U.S. and on the international scene.

In the early 1940's, as you know, very intensive research was conducted in the U.S. and elsewhere on processes for separation of uranium isotopes for military purposes. In this country, this research included work on electromagnetic separation, gaseous diffusion, thermal diffusion, gas centrifuge, and photochemical methods. The U.S. goverment successfully built plants which operated on a production scale using three different processes: thermal diffusion, electromagnetic (calutron), and gaseous diffusion. Photographs of some of the hardware are shown in my first chart (Chart 1). In view of the relative economics and performance, however, the thermal diffusion and electromagnetic plants were soon shut down, and we continued with gaseous diffusion, expanding its capacity over the years.

I think our experience since the early "crash program" days of the enrichment business underscores some points I will note here and return to later in more detail (Chart 2). First, selection of an enrichment process required making trade-offs and striking balances among various features of importance, such as separation factor, throughput, inventory, reliability, energy requirement, status of technology, and cost. From the production point of view, economics and scale of production are decisive points. These factors are weighted differently, however, if still other objectives are important, such as proliferation concerns or independence of supply. Also, some factors, costs in particular, vary from nation to nation. It should be noted here that the cost of uranium enrichment, either by diffusion or by the advanced processes, represents only a small part of the overall cost of power systems or military systems. Enrichment costs, therefore, may not be a very decisive factor for many nations. Another point, which should be rather obvious (Chart 3), is that deployment of an enrichment technology, like any other, proceeds along an inevitable progression of steps from the scientific phase to production. I only point that out as a reminder which I still find useful in gaging the status of various technologies.

URANIUM ENRICHMENT OVERVIEW

With this background in mind, I would like now to summarize the international uranium enrichment picture as we see it today and anticipate it to be over the next several years. There are a number of organizations and countries which will be competing to supply enriched uranium to the free world, and even more which will be pursuing enrichment technology by a number of processes on an R&D scale.

The U.S. Program

The U.S. program encompasses production-scale work on gaseous diffusion and gas centrifuge, and advanced engineering development of several other processes (Chart 4). In gaseous diffusion, we are two years away from completing the 10-year Cascade Improvement (CIP) and Cascade Uprating (CUP) programs, which together will increase the total production capacity of the our three gaseous diffusion plants by 60 percent, or by about 10.1 million SWU/yr at full power. I will be using the term Separative Work Unit, or SWU, frequently in my comments because it provides a necessary basis for quantifying enrichment plant capacities and costs regardless of the particular process involved. This increase in plant capacity is being achieved for a capital investment of less than $1.5 billion, a very favorable cost when compared to the investments needed to provide this much capacity by new plants based on any known enrichment process. Over half of this capacity gain, the 5.5 million SWU/yr associated with CIP at full power, will require no increase in the power needs or operating costs of the plants and therefore will provide a significant increment of separative work at a unit cost of $22/SWU. This is not an estimated cost, but one we are really achieving. Again, it represents a very favorable cost in the enrichment market of today when separative work is being priced at $88.65/SWU. At the completion of CIP and CUP, the operating cost of the gaseous diffusion complex will be about $60/SWU when the plants are operating at reasonable capacities. The CIP/CUP expansion is about 75 percent complete and is proceeding very well on all fronts: cost, schedule, and technology performance.

In our gas centrifuge program, the major focus is construction of the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. At the present time, we are heavily involved in the technology support, design, and industrial-base-building phases of the project. The first block of capacity, 2.2 million SWU/yr, is scheduled to be completed in 1988; and the full 8.8 million SWU/yr is intended to be brought on line consistent with the demand, perhaps by 1993. The total project cost is estimated at $5.1 billion.[1] When the capital amortization, interest during construction, and operating costs are combined, the projected enrichment cost is $117/SWU. Of this, about 80 percent is for capital amortization and 20 percent for operating cost.

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[1]In FY 1980 dollars.

The present DOE Advanced Isotope Separation (AIS) program involves parallel R&D work on three promising processes. By the mid 1980's we expect to see a development module in operation at a level of production and in a configuration which will help us evaluate the potential and status of the technology for production use. Following the development module, we would anticipate the need for pilot plant demonstration (in about 1987) prior to the first production module, which could be in operation by the early part of the 1990's. These development stages will provide confidence in the large-scale commitment to a new technology at acceptable risk.

Other Programs

I would next like to outline the uranium enrichment picture in the rest of the world (Chart 5). Eurodif, a multinational gaseous diffusion project in Tricastin, France, is financed by France, Italy, Spain, Belgium, and Iran, and is in the construction completion and start-up phase. Power for the plant will come from nuclear reactors also under construction at the Tricastin site. By 1982, Eurodif will have a capacity on-line of 10.8 million SWU/yr, which is over one-third the installed U.S. capacity in 1982. Urenco, a multinational gas centrifuge project sponsored by the United Kingdom, Federal Republic of Germany, and the Netherlands, is in commercial operation. It is presently a much smaller project than Eurodif, but Urenco is steadily expanding its capacity. Present schedules are for 1 million SWU/yr by 1982, and Urenco has talked about having up to 10 million SWU/yr by 1990. Some of Urenco's customers in countries which are Urenco sponsors have recently cancelled U.S. enrichment contracts. The USSR, as shown here, is a significant supplier to the Western European market in particular, with about a 3-million SWU/yr business expected in the early 1980's. The Japanese have an aggressive gas centrifuge program and expect to achieve the significant capacities shown in my chart. The projects being built in South Africa (UCOR) and those being discussed by Brazil both employ aerodynamic processes and are of relatively low capacity from a commercial standpoint. One of the big marketplace uncertainties may prove to be Coredif, another multinational gaseous diffusion project in France, which could, if it were undertaken in the near future, introduce a substantial amount of separative capacity into the supply picture by the late 1980's. We note, however, that in that time frame Coredif will not likely be competitive with advanced processes being developed in the U.S. program.

Project Highlights and Illustrations

My next chart (Chart 6) places both the U.S. and foreign projects on the same time scale. I must emphasize that these are just the enrichment projects which are either under way or being actively considered. Many nations throughout the world are also engaged in research and development of uranium enrichment by diffusion, centrifuge, aerodynamic, laser, electromagnetic, chemical, and other techniques.

To illustrate some of these projects, my next few charts give you actual views of some of the work going on around the world.

Chart 7 is an overview of the three U.S. gaseous diffusion plants at Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee.

Chart 8 shows an improved diffuser, containing more efficient gaseous diffusion barrier, being connected to an improved and uprated compressor as part of the diffusion plant CIP/CUP expansion.

Chart 9 is an overview of the Eurodif project site at Tricastin.

Chart 10 is a view of the diffusers being installed in the Eurodif plant.

Chart 11 is a conceptual drawing of the U.S. centrifuge plant (GCEP) on the Portsmouth site.

Chart 12 shows the evolution of centrifuges, including the type that is to be used at the Portsmouth site.

Chart 13 is a photograph of some Urenco centrifuges in the Almelo cascade.

Chart 14 shows a Russian ship being loaded with UF_6 cylinders.

Chart 15 is a photograph of the South African pilot plant at Valindaba.

I think some of the complexities of the enrichment business are apparent from what I have just shown you. While some claim that there is no future in gaseous diffusion, France and her partners are investing several billion dollars in the process right now. Obviously, some feel comfortable about the future of gaseous diffusion, although several nations, including the U.S., are investing large sums of money in centrifuge development. While the U.S. has no large-scale production interest in aerodynamic processes, we see some nations pursuing that technology. And, in many places, there is work on other processes, and technical experts debate over which is or will be the best.

MARKET ISSUES

In order to place my thoughts and conclusions regarding the uranium enrichment enterprise in proper context, I feel that it is appropriate first to build a foundation by considering some of the more important issues in detail. I would therefore like to discuss briefly the status, complexities and uncertainties of uranium enrichment, dealing with market issues, technology issues, and finally, with several other relevant issues.

Demand Uncertainties

Like many aspects of energy planning, the demand picture for enriched uranium is very uncertain. Even well-based projections of demand over the short term, five to 10 years, are recognized as having significant uncertainties today which affect our immediate strategies of assuring adequate supply. But I feel that we must force ourselves to look even beyond this period, say to the year 2000, to develop an acceptable foundation of policies and plans which will meet our national objectives. As might be expected, the range of demand uncertainties in this more distant time frame is much broader, but that broadness only emphasizes the importance of one of my major conclusions -- that of maintaining flexibility by keeping our available options open. Two areas which I would like to discuss in presenting this picture are the U.S. domestic demand and the expectations for supply of foreign demand by U.S. enrichment plants.

Range of Domestic Demand

One of our most difficult planning tasks involves making estimates of the separative work that will be needed in the U.S. over the next several years. Such a problem is almost intractable, and I admire the experts who, armed with mountains of data, do an admirable job in giving us these projections. I personally take a little different approach to this problem when I am thinking about how much enrichment capacity we will need, say, 15 years from now. Certainly we need a best estimate of what the demands will be, but I think it is also very important to consider the area of uncertainty associated with that estimate. Thus we develop, as shown in Chart 16, the planning estimate (we call it a "mid" case), and in addition we develop estimates of the boundary conditions which we think are reasonable limits of the area of uncertainty on demands. The estimates are based on the following:

1. A "mid" case, in which there is very modest growth beyond the present DOE domestic enrichment services contract level, about 200 GWe, up to a level of about 250 GWe by the year 2000, representing about 30 million SWU/yr demand. This level could probably be achieved within the present legal and regulatory environment provided a reasonable political situation develops by the mid-1980's on the use of nuclear power in areas where it has distinct economic advantage.

2. An "upper" case, in which nuclear power is deployed in this country up to the limits of the present capacity of industry to build and activate reactor systems. This would result in 550 GWe by the year 2000, requiring about 55 million SWU/yr but could only be achieved, in my opinion, following major changes in the legal and regulatory framework, as well as by the awakening of a national consensus of the need for the ambitious use of nuclear power in preference to burning oil and gas. Such a scenario does not seem likely today, but it cannot be entirely dismissed when one considers the millions of additional people who will enter the U.S. job market by the 1980's, the erosion of electrical utility generating reserve likely during the next five years, and the decreasing security and increasing costs of our oil supplies.

3. A "lower" case, virtually a non-nuclear one, in which it is assumed that, to the year 2000, only those nuclear reactors now having construction permits and over 10 percent constructed will be completed. This results in about 125 GWe U.S. nuclear power in the year 2000, or a requirement of about 15 million SWU/yr.

Range of Foreign Demand for U.S. Enrichment Services. At the present time, DOE has enrichment services contracts representing about 100 GWe of foreign nuclear power, representing about one-third of our total enrichment business. There have been delays in some foreign nuclear projects not unlike those in the U.S. and, in addition, some of our customers are apparently switching to other enriched uranium suppliers. Considering these factors, I believe some defensible scenarios are (Chart 17):

1. A "mid" case, where on a net basis we merely maintain our present 100 GWe contract level, equivalent to about 10 million SWU/yr, even while foreign nuclear power growth continues.

2. An "upper" case, in which we are able to compete successfully for a foreign market which is assumed to be growing sufficiently beyond indigenous supply capabilities to create new business opportunities. This might lead to contracts for as much as 175 GWe by the year 2000, or about 20 million SWU/yr.

3. A "lower" case, in which I have assumed that loss of our market position would continue until we reach a level of 50 GWe in 1985. representing a demand of about 5 million SWU/yr thereafter.

Ranges of Demands for U.S. Supplied Separative Work. Combining the demand ranges I have just presented for our domestic and foreign customers results in the demand picture shown in my next chart (Chart 18). Looking at the year 2000, I believe it is reasonable to project a "lower" limit at about 20 million SWU/yr, and "upper" limit at about 75 million SWU/yr, and a "mid" point at about 40 million SWU/yr.

I realize that the demand ranges I have just projected are very wide, a reflection of the scope of uncertainties involved in projecting demand through two decades. We have found over the years that the official

estimates, based as they must be in the contractual world, have a large time constant. What I have tried to do is look beyond the immediate contracts and use other considerations to come up with what I believe is a realistic estimate of the likely limits of demand. There will be those who would argue with my numbers, but the absolute values of the limits are not that critical for the development of planning strategy. Others might argue that the breadth of these ranges makes it impossible to develop meaningful strategies. I disagree with this latter point and would submit, in fact, that only by taking a cold, hard look at the dimensions of our demand uncertainty can we begin to focus on the real issues and formulate strategies which do have meaning.

Supply

I would like to turn now to the supply side of the picture. Earlier, I identified the potential suppliers. What I want to do next is to place the supply projections on the same scale as the demand estimates.

U. S. Supply. My next chart (Chart 19) presents the demands projected earlier for U.S. enrichment services -- demands for both domestic and foreign reactors -- along with our gaseous diffusion and gas centrifuge capacity estimates. It appears at first glance that we will have ample gaseous diffusion capacity to satisfy our demands through the 1980's and that a combination of fully powered gaseous diffusion and GECP could cover the demands of the "mid" case until the early 1990's. However, gaseous diffusion production (as distinct from capacity) may be severely limited by deliberate or unavoidable shortfalls in electrical energy. The ability to absorb these shortfalls is indeed highly desirable as has been demonstrated on numerous prior occasions when the gaseous diffusion complex has been used as a major flywheel for the electric supply systems which power it. Therefore, it is apparent that we need both to proceed with GCEP and to preserve the option to obtain near-design power for the diffusion plants in the longer term future. I will mention this again later.

Free World Overview. I have summarized in my next chart (Chart 20) the free world supply/demand picture as it appears today. It seems likely that there could be production capacity exceeding demand through the 1980's unless some ongoing programs are cut back. By the early to mid-1990's, however, there seems to be a need for at least some additional capacity, with several suppliers having a base from which to expand competition. The picture, however, is very fluid and very uncertain. France will have the Eurodif project completed, but I feel that the proposed Coredif facility is more speculative, as are the planned Urenco centrifuge expansions beyond 1990. There may well be separative work overcapacity in Europe into the early 1990's, with much competition in the marketplace and likely decreased opportunities for the U.S. Japan has an aggressive gas centrifuge program and is obviously working toward achieving a large degree of independent supply. Russia can be expected to continue offering separative work at competitive prices.

TECHNOLOGY ISSUES

There are many ways to separate uranium isotopes, and the situation on uranium enrichment technology has as much uncertainty as that on supply/-demand. I would like to turn now to this subject and discuss some elements of the technology picture.

Readiness

The first point I want to discuss is the status of various enrichment processes with respect to the large-scale supply of separative work; that is, where some of the major processes stand today in the evolutionary sequence I mentioned earlier.

Gaseous Diffusion. Gaseous diffusion is a highly developed commerical process that has been utilized in the U.S., United Kingdom, France, Russia, and China. As noted earlier, gaseous diffusion capacity expansion is underway in this nation and in France at the present time. The three U.S. gaseous diffusion plants are very efficient and are proven highly reliable -- over 99 percent on-stream availability for decades (Chart 21). The U.S. plants are in good condition and absolutely capable, with comparatively modest support, of being operated efficiently at least through the rest of this century. The major capital expenditures will most likely be for projects needed to assure continuing safe and reliable operating conditions and to comply with environmental and other regulations -- compliance that is necessary for any process.

Gas Centrifuge. Gas centrifuge technology has been developed to the point where it is ready for large-scale deployment, as evidenced mainly by the GCEP and Urenco programs (Chart 22). In this country, we are just entering a demanding but essential phase where the large U.S. industrial infrastructure required to support GCEP must be developed. The recent selection of machine suppliers was a positive step in this regard. Once there is an adequate industrial base, gas centrifuge capacity is economically competitive on a much smaller scale than gaseous diffusion. Because only a few centrifuges are needed to span the fuel enrichment assay range, gas centrifuge capacity can be added in small blocks and thus more precisely match the demand curve. Centrifuge capacity can also be added on a schedule that is shorter than the reactor construction schedule which drives the demand.

Laser/Plasma. The laser and plasma processes being developed now within DOE's AIS program are nearing the end of the scientific feasibility phase and, for the most part, appear promising at this point. The next step is construction and operation of an integrated development module, which is an essential step for evaluating their commerical readiness. One U.S. venture (Jersey Nuclear-Avco Isotopes) and many foreign countries are studying laser processes.

Aerodynamic. Most of the work on aerodynamic processes for uranium enrichment has been done in West Germany, where the Becker nozzle process is being developed. Versions of aerodynamic processes are presently in

the pilot plant stage in both Germany and South Africa. It has been demonstrated that these processes will separate uranium isotopes, but they have yet to pass the test of economic feasibility. Because of the limited impact of separative work costs on nuclear power costs, the availability of this technology to these nations may determine its use in spite of its unfavorable economics.

Chemical Exchange. Chemical exchange is an established isotope separation process, being the best process for some of the light elements such as hydrogen or boron. The stage separation factor is small compared to some other processes, but many stages can often be combined in equipment of small volume. A chemical exchange process for uranium enrichment was actually developed and brought to a pilot plant stage at Oak Ridge during the 1950's, but was abandoned as not competitive with gaseous diffusion. More recently work has been conducted at Mound Laboratory. The French have also recently announced a chemical exchange process which they claim is very attractive because of the inherent difficulty of using it for highly enriched uranium production. Arrangements are currently being finalized to obtain access to the French technical data to permit our evaluation of this claim.

Other. There are a number of other techniques which have been considered or proposed for uranium isotope separation. These include the "Haga" radial separating nozzle centrifuge process, vortex tube processes, various diffusion processes, molecular beam processes, phase equilibrium processes, and photoexcitation and electromagnetic processes, plus a few which defy conventional classification. Many of these have been evaluated and not pursued further, usually because of clear lack of competitiveness with developed processes. Others are still being considered, but none is as far along the deployment path as those described earlier. One of the interesting aspects of the enrichment business is the opportunity to see many new ideas. We look at each one carefully so that we can capitalize on any real technological advance. Furthermore, even processes with no chance of being competitive must be evaluated for their proliferation potential.

Energy Requirements

Gaseous Diffusion. My next chart (Chart 23) summarizes the energy requirements of some of the major enrichment processes of interest today. One of the chief disadvantages often cited for the gaseous diffusion process is its relatively large energy requirement, 2300 kWh/SWU. To dwell on this process aspect is unfortunate, becuase it obscures the fact that the energy used to enrich uranium via gaseous diffusion is still multiplied thirty times when that uranium is burned in a nuclear reactor. Put another way, a nuclear reactor need allocate only about three percent of its output to the gaseous diffusion plant which enriches its fuel. This is less than the in-station energy requirements of at least five percent for power plants.

One of our most serious concerns is the growing vulnerability of the U.S. diffusion complex to power input. As the CIP and CUP are completed, the capacity of the plants to utilize power will increase to 7000+ Mwe,

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with proportionately higher productivity. However, the plants have recently been used increasingly for the benefit of others as the seasonal load-leveler or "flywheel" of our electric suppliers. These have been appropriate actions. It is important, however, to assure that such short-term actions are not taken in a manner which could jeopardize the possibility of acquiring electrical power at some future date. Such a de facto abandonment of the valuable option to utilize the high productivity of the diffusion plants in the future would add an unnecessarily large element of risk to the U.S. capability of meeting possible future separative work needs. I would urge a careful consideration of the possible unfavorable consequences of diffusion plant power contracts frozen at lower levels.

Gas Centrifuge. One of the primary advantages of the gas centrifuge process is its relatively modest energy requirement, on the order of 130 kWh/SWU, or about five percent of that for gaseous diffusion (Chart 24). This greatly increases the attractiveness of gas centrifuge vis-a-vis diffusion in the case where energy costs escalate substantially faster than labor and construction costs. A fully deployed gas centrifuge plant also gives the U.S. a good low-energy separation process in the event that power for our diffusion plants is not available.

Laser/Plasma. The laser isotope separation processes appear at this point to have energy requirements of the same order as the gas centrifuge process. The plasma separation process may require somewhat more, but will still only be a few hundred kWh/SWU or a small fraction of the gaseous diffusion requirements.

Aerodynamic. (Chart 23) Our present understanding of aerodynamic processes is that they will require more energy than gaseous diffusion without offering compelling offsetting advantages. This is a primary reason why we abandoned any significant work on these processes in the U.S.

Chemical Exchange. Chemical exchange processes are projected to require less than one-third of the energy for gaseous diffusion, much of this requirement in the form of heat. Other considerations, however, such as large uranium inventories and long equilibrium time, make these processes less attractive.

Costs

Gaseous Diffusion. The U.S. gaseous diffusion plants are virtually in place today, a fact which enhances the economic competitiveness of our diffusion capacity. The principal operating cost component of gaseous diffusion is the electrical energy cost. The operating costs from the U.S. gaseous diffusion plants vary with the diffusion plant power level. Above modest power levels, the operating cost from the U.S. plants is about $60/SWU, $55 of which is for energy. This is a very attractive cost. For a new diffusion plant amortization of capital could run the unit cost up to about $140/SWU.

Gas Centrifuge. The GCEP project, fully deployed at 8.8 million SWU/yr capacity, is expected to produce separative work at a cost of about $117/SWU. We believe this is less than the present cost picture for Urenco. It is important to note that of the $117/SWU U.S. cost, most is for the capital write-off. Once the GCEP plant is built, the operating costs will be very attractively low, producing enriched uranium at about $20/SWU in terms of out-of-pocket costs.

Laser/Plasma. One big appeal of these new technologies is their potential to reduce the unit cost of separative work from uranium enrichment plants by a factor of two or more, a primary reason for our enthusiasm about the technologies. At the present time, however, the development of these technologies is not yet sufficiently advanced to allow substantiating this potential.

Aerodynamic. Our estimates of the cost factors of aerodynamic processes place them in a region comparable to gaseous diffusion. In the specific area of operating costs, large power costs, also comparable to those of gaseous diffusion, would certainly be expected from aerodynamic processes.

Chemical Exchange. The French have claimed that the chemical exchange process unit cost of separative work would be comparable to that for gaseous diffusion. We do not have any definitive information on either capital investment or operating costs which allows validating the French claim. The only distinctive process characteristics appear to be a power requirement somewhat lower than gaseous diffusion and the expectation of competitive costs from smaller plants.

Technology Potential

Gaseous Diffusion. In the U.S., past expansion of our gaseous diffusion capacity has traditionally capitalized on technology advances, with CIP and CUP being the current examples. The nature of the process makes it difficult to justify incorporation of improvements except in a fairly major hardware changeout program like CIP. The U.S. technology is very efficient and mature, with stages optimized, so that there is little opportunity seen in the future for the major improvements which have characterized prior programs. The large hardware volumes of the Eurodif plant suggest to me that some efficiency improvements might still be possible in France, possibly increasing their plant capacity.

Gas Centrifuge. The U.S. gas centrifuge technology being utilized in GCEP is very advanced. Nevertheless, there are still opportunities for further gains of significant magnitude in our centrifuges which can be economically exploited in the latter portions of GCEP, in replacement machines in GCEP operations, or in future plants.

Most of the present development effort is directed towards assuring the success of the initial GCEP machines and process. These programs include efforts aimed at assuring plant and machine design performance and reliability as well as assuring that the plant systems, components, and machines will be built within cost. An attractive feature of our centrifuge process is the opportunity to continually upgrade the plant through replacement of machines that wear out or fail in operation.

There is a continuing basic research and development program aimed at producing a lower cost centrifuge process. Improvements can be made in increasing the separation factor and throughput of each machine and in reducing the unit cost of machines, the cost of process systems, and operating costs. In laboratory centrifuges very similar to the GCEP design, we have already demonstrated a ten percent gain in performance. A number of other designs and concepts are being theoretically and experimentally evaluated here in Oak Ridge, at the University of Virginia, and at AiResearch. Important advanced programs are under way at LASL and LLL.

Laser/Plasma. The full potential of the advanced technologies is not yet known; programs in the U.S. are aimed at better defining this potential. Expectations are that processes based on these technologies may be the most economical to meet future U.S. needs.

Aerodynamic and Chemical Exchange. Even operating near theoretical limits would not appear to offer decisive advantages from these processes for the U.S. Our interest in these two areas is based more upon having a sound foundation for assessing their nuclear proliferation potential than for deploying processes having characteristics and economics very similar to gaseous diffusion.

Technology Summary

In my next chart (Chart 25), I have summarized some technological features of various processes. I noted these features earlier, and they are the principal ones which, in combination, determine the attractiveness of an enrichment process. I have ranked them in that context using gaseous diffusion as a reference. As you can see, one of the general features, except for the advanced processes which are still in the development phase, is that one process' strength is often another's weakness. For this reason, the answer to selection of a specific process is not altogether clear-cut. As I noted previously, the weights of the various parameters in the selection equation can and do vary from nation to nation and from time to time. In some measure at least, this reconciles a GCEP project in the U.S. and a Eurodif project in France. But there are also other factors involved, and I would like to turn to these next.

OTHER ISSUES

Proliferation

The current attention to the impact of the availability of fissile material on a worldwide basis is addressing a danger that is very real. One has only to consider the Pakistani centrifuge effort and South African aerodynamic effort to recognize the seriousness of this problem. Proliferation has been a concern of ours since the inception of the enrichment business, and there are few areas where I have concentrated as much of my own time over the years as I have on the proliferation issue. In giving you some of my thoughts on this subject, I would first like to describe some aspects of the proliferation implications of various technologies. Following that, I would like to deal with the subject in somewhat broader perspective.

Gaseous Diffusion. Gaseous diffusion is regarded by some as an unattractive technology for a proliferator to choose even though it is the uranium enrichment process most used to date. This conclusion stems from the inherent low separation factor, large energy requirements, and rather large hardware used in production plants. These are, in fact, substantial barriers to both dedicated clandestine facility construction and diversion, and therefore it is probably accurate to rank this technology as one of the least attractive present proliferation routes. However, the fact that five nations have built atomic weapons using gaseous diffusion product should be a reminder not to dismiss the possibility of small diffusion equipment altogether.

Gas Centrifuge. The proliferation risk of the gas centrifuge has long been recognized as relatively high because of the small number of machines required in series to achieve full enrichment. Consequently, the U.S. has always treated this technology as highly classified. Despite these U.S. efforts, a number of other nations already have independently developed gas centrifuge technology to meet their particular needs.

Laser/Plasma. These processes are currently too technologically advanced to represent an immediate proliferation risk. There are some broader implications here, however, which I will discuss in a moment.

Aerodynamic. As with gaseous diffusion, the relatively large energy requirement per separative work unit and relatively small separation factor would at first seem to place aerodynamic processes rather low on the list from a proliferation risk standpoint. Compensating features, however, appear to be that the separating elements in aerodynamic processes are not as technically formidable as efficient gaseous diffusion barrier, and the lower inventory allows faster equilibrium. Furthermore, the mere existence of the South African and West German efforts illustrates the problem of danger from available technologies.

Chemical Exchange. Proponents of chemical exchange, notably the French, argue that this process is practically proliferation-proof because of the large in-process inventories and long equilibrium times. I believe this argument, which certainly has some basis in fact, is still potentially disarming for two reasons. First, it discounts too much, I believe, the ingenuity of engineers who might be challenged with the task of developing rapid, low hold-up contactors. Second, it fails to recognize that 60 percent of the separative work going into 90 percent 235U weapons material is done in getting to three percent enrichment. Ready access to three percent reactor fuel material would therefore make weapons production much easier to any nation.

Having looked at some process-specific proliferation considerations, I would now like to talk about this subject in somewhat more general terms. I would like to do this by addressing three rather widespread misconceptions which I believe have clouded thinking about this issue (Chart 26).

The first is the idea that there are overwhelming differences in proliferation potential among currently available technologies, differences which are presumed to determine a few select pathways on which one can concentrate. There is an element of truth to this idea. Certainly, converting a large production enrichment plant producing reactor-grade material to weapons material production, all other things being equal, would be much more difficult and harder to conceal with gaseous diffusion stages than through the use of centrifuges. But I believe it is important to recognize that any technology being developed for enrichment of uranium for power reactor fuel constitutes a proliferation risk. The nozzle technology being developed in West Germany and being considered for prototyping in Brazil, the UCOR process in South Africa, the centrifuges in Japan and Europe can all, in fact, be applied to weapons production. Even improved chemical exchange methods should not be entirely ruled out at this time. The decision of which technology to use is not only a technical one, but also very much an individualized national consideration, based on other factors such as specific skills and talents, available materials and technology bases, and goals and objectives.

The second erroneous idea is that of technology constancy. Too often we base our policies and actions on our assessments of current technology status rather than potential future developments. Policy representations should be reviewed regularly, because enrichment technology is very dynamic. This is particularly true in the case of the advanced processes. Today, it appears that the laser and plasma processes are so technologically complex that they will not pose a proliferation risk, especially from the less-advanced countries. In the future, especially with success in their development and demonstration, this picture could change markedly.

The third misconception is related to the first two and is, perhaps, a broader restatement of them. It is the idea that enrichment poses substantially less of a proliferation risk than the fuel reprocessing route. Clearly, the national policy on discouraging nuclear proliferation has focused predominantly on reprocessing in recent years. There are some reasons for this. Enrichment technology is classified by most countries, while reprocessing technology is not. Uranium enrichment is already a well-established fuel cycle step and is also protected for proprietary reasons, whereas chemical reprocessing for plutonium is not yet firmly established. Of course, enrichment and reprocessing represent different types of proliferation risks. For example, reprocessing may lead naturally to the isolation of weapons material, while an enrichment plant built for reactor fuel must be deliberately diverted to produce weapons materials. I would urge a balanced position in evaluating proliferation aspects of enrichment and reprocessing technologies. In this regard, the serious proliferation questions surrounding the advanced processes, in my judgment, deal not with precise technical details right now, but with potential future developments. As the advanced processes succeed and introduce less expensive separative work into the market, it is inevitable that the 235U route will become correspondingly more attractive vis-a-vis the reprocessing route.

At one point, the U.S. was the unchallenged reliable enrichment supplier to the entire free world. Today, enrichment technology has been proliferated on a wide scale. To some extent, this trend has been in response to U.S. actions such as closed order books and, more recently, to our own nonproliferation initiatives, which have not always had the effect we intended. The issue before us today is no longer how to prevent any proliferation of enrichment technology. Some has already occurred. This issue is to prevent further spread of this technology, to the extent we can, and to take whatever steps we can to preclude the use of this technology in weapons production. The best way to deal with the issue of enrichment proliferation risk, (Chart 27), in our opinion is: (1) to reduce the incentive to proliferate by establishing the U.S. as a dependable, low cost supplier of enriched uranium, and (2) to work jointly with other suppliers to reduce the opportunity to proliferate using all our available tools like security, classification, export controls, and safeguards.

Safeguards

As you are aware, GCEP will likely be made eligible for International Atomic Energy Agency safeguards inspection as a consequence of the US/IAEA agreement which is before the Senate for ratification. Union Carbide Nuclear Division has been assigned by DOE to assume a lead role in a program to develop international safeguards options for GCEP. In cooperation with other DOE contractors, we are developing inspection methods, techniques, and instrumentation that will improve the capability of the IAEA to effectively inspect enrichment facilities.

Based on our experience in uranium enrichment, we regard the application of international safeguards to the GCEP with some apprehension in the area of specific details of implementation. We understand the importance of the policy of applying IAEA safeguards to U.S. facilities as a means of encouraging the widest international adherence to the Nonproliferation Treaty. We are, however, concerned about the potential risk of the dissemination of enrichment technologies as a byproduct of international inspection. As I just mentioned, it is imperative that the U.S. discourage the further spread of enrichment technologies, particularly the advanced technologies, including the classified gas centrifuge. The U.S. has consistently encouraged other nations who are developing gas centrifuge enrichment to protect their technology to limit its dissemination. The London Supplier's Group Agreement has also helped to achieve a more universal recognition among the technology developers of the need to control the spread of this technology.

Safeguards inspection by the IAEA must be implemented in a manner which will protect sensitive technology, as well as assure that the technology is used only for its stated purpose. The IAEA in its safeguards agreements recognizes the need to protect commercially sensitive information; and in the U.S., as well as in other countries, the laws and security procedures for classified information will necessarily limit the degree of access and the extent of information that will be provided to IAEA personnel.

IAEA safeguards at enrichment plants should be capable of detecting diversion of significant amounts of uranium, particularly the low-enriched product, and of detecting misuse of the facility to produce highly enriched uranium. These safeguards rely primarily on verifying the material accountancy records of the facility and secondarily on assuring that significant quantities of undeclared feed uranium are not introduced into the plant. This strategy does not require IAEA access to the sensitive portion of the plant and can be effective in accounting for significant quantities of ^{235}U for plants with total capacities of less than 1 million SWU/yr. Because of limitations on measurement accuracies, IAEA safeguards in larger plants will necessarily become more intrusive if they are to maintain a level of effectiveness comparable to that achievable in smaller facilities. Since the IAEA has only limited experience in safeguarding enrichment plants and only limited resources, we would expect that the safeguards will evolve as the IAEA experience grows, as methods are refined, and as the sizes of the inspected facilities increase.

The ability of the U.S. to foster nonproliferation objectives internationally has been largely a result of the leadership position in nuclear energy that the U.S. in the past has developed and maintained. The application of IAEA safeguards in U.S. facilities will provide an opportunity to assist the IAEA in enhancing its effectiveness and thus promote nonproliferation; the challenge is to protect simultaneously against the dissemination of advanced enrichment technologies which would erode the ability of the U.S. to encourage nonproliferation policies worldwide.

Customer Concerns

Even in a commercial environment for a nuclear power utility, other factors may override the enrichment cost factor. Enrichment services represent only one-third of the nuclear fuel cost and only one-tenth of the overall cost of electricity from currently operating nuclear stations, a cost which is dominated by the interest on invested capital for power production. Without detracting from the large dollars associated with enrichment and the importance of economics to the enrichment business, it can still be seen that the economic leverage is not so great as to prevent other factors, such as predictability and assurance of supply, from assuming a decisive role in supplier selection. The loss of exclusivity of the U.S. position in uranium enrichment is irrefutable evidence of this point. I would like to note briefly some of the factors which I think caused this shift away from the U.S. Inevitably, the U.S. could not hope to retain its monopoly position indefinitely in a world increasingly sensitive to the security of national fuel supplies. However, we likely accelerated this trend away from the U.S. as a reliable supplier by such actions as closing our order books for four years and turning away from a requirements-type contract which customers prefer. In addition, superimposing terms stemming from the 1978 Nuclear Nonproliferation Act certainly has not catalyzed any foreign consensus that the U.S. is in fact trying to "provide a reliable supply of nuclear fuel to those nations and groups of nations which adhere to policies designed to prevent proliferation," as Title I of the Act states. Many of our actions over the last few years have been ostensibly taken either to reduce the uncertainty in our demand estimates, which would allow more precise planning, or to diminish proliferation, or both. My earlier charts showed that there is still considerable uncertainty in the demand picture for our plants. I would question whether our nonproliferation objectives have been strengthened either. Both points underscore the importance of an accurate understanding of the customer's viewpoint.

Balance of Payments

In my discussion of the supply/demand picture, I noted that about one-third of our toll enrichment contracts are for fuel for foreign reactors. This represents a cash flow to the U.S. of $470 million in FY 1979. Using the "upper" and "lower" limits from my foreign demand projection (Chart 17), I have estimated a range of our possible income from foreign sales. There is a potential for from $0.5 to $2.0 billion/yr in foreign sales, depending on the share of the foreign market which we may ultimately have. I believe this represents a very important contribution to reducing our balance of payments deficit. This is one factor which should encourage us to seek a larger foreign trade in U.S. separative work.

Uranium Resources

There are three points which I would like to make in connection with the relationship between enrichment and uranium supply. The first is the point that, within fairly wide boundaries, enrichment and natural uranium

feed are interchangeable. For example, we can supply 25 percent more product from an enrichment plant by increasing tails assay from 0.20 to 0.30 percent ^{235}U, if we need to, but this would require 50 percent more natural uranium feed.

My second point is that, for any given combination of cost of separative work and cost of natural uranium, there is an economic optimum tails assay. For the present conditions, this is about 0.20 percent ^{235}U. If separative work becomes cheaper via an advanced enrichment process or feed becomes more expensive because of scarcity, then this will drive the optimum tails assay lower, enabling us to recover economically more of the ^{235}U from the feed. One big appeal of the advanced technologies is this resource conservation aspect.

My third point is that there should be a natural partnership between uranium suppliers and uranium enrichers. In spite of the complications involved in arriving at mutually suitable arrangements, a nation possessing enrichment technology, say the U.S., could conceivably link up with nations having large uranium reserves in excess of their domestic requirements, say Canada or Australia, to satisfy proliferation objectives of the enricher, resource management objectives of the miner, and business objectives of both.

Business Approaches

There are several institutional arrangements possible for the U.S. enrichment business. These include concepts involving government agencies, various types of government corporations, and different private ownership alternatives. Each of these options has advocates and opponents, and there has been considerable discussion over the years about this issue. There are two comments I would like to offer.

First, I think protracted debate of the enrichment plant ownership issue was the key reason why our order books were closed during the four years starting in 1974. There was natural reluctance to commit to increased capacity if that task were about to be turned over to private industry. We should find ways in the future to keep arguments about the longer range institutional issues from rendering us unable to make current business management decisions which, after all, will also end up impacting the longer range picture.

Second, I personally do not believe that the specific institutional approach chosen is as important as the basic guiding principles established for the enrichment industry. I believe that any of several frameworks for the enrichment business would work well, provided they are placed on a truly businesslike basis. This includes permitting flexibility in marketing, flexibility in pricing, flexibility in production, flexibility in stockpile management, and flexibility in acquiring and expending capital. The structure should permit true long-range planning, where investments in R&D and plant and capital equipment can be planned over a reasonable time, where production levels can be scheduled and held with reasonable assurance, and where decisive actions can be taken to increase capacity as it is needed.

CONCLUSIONS

I have addressed some of the issues facing the U.S. enrichment business of today as well as issues involved in exploiting the attractive potential of the advanced uranium enrichment technologies. In drawing some conclusions as to what should be our course during the next few years, I recognize that there are considerable uncertainties which must be taken into account--in the market, in the actions of foreign enrichers, and in the area of new technologies. My conclusions must, of course, rest on some assumptions about the goals and objectives of the enrichment business for the U.S. My own current perception of our U.S. enrichment objectives is:

- That the U.S. wants to be recognized as a dependable, low-cost, long-term enrichment services supplier domestically and overseas. This can result in substantial economic benefits to the U.S. and reduced pressure to proliferate enrichment plants abroad.

- That the U.S. wants to be the world leader in enrichment technologies, not only because of the benefits this brings to the U.S., providing and protecting options to use the cheapest and best process in tracking demands, but also so we can know just what options other nations might have in using other technologies to enrich uranium.

- That the U.S. enrichment business objectives must be pursued with due concern for proliferation and safeguards.

- That the U.S. needs to operate the enrichment business in the long run in a manner that gives proper consideration to the importance of conserving our uranium resources and its contained ^{235}U.

- That the U.S. wants to maintain our present position of self-reliance and independence in the nuclear power option and to influence the development of that option elsewhere.

- That we want to preserve a wide range of options in the enrichment business because of an uncertain future:

  - options to ensure the viability of our existing capacity,
  - options to respond to changes in power availability for our diffusion plants,
  - options to respond to upturns as well as downturns in the market for separative work, and
  - options to take advantage of technological breakthroughs.

Now, with those assumptions as to what the U.S. enrichment programs goals and objectives are, I offer the following conclusions from our review of the situation today and our view of the future.

Diffusion Plants. We must maintain a reasonable stockpile of enriched uranium to supply our customers and to provide protection to them in the event of interruption of enrichment plant production. The U.S. gaseous

diffusion plants will supply about half of the U.S. and foreign separative work during the remainder of this century and are the foundation of our enrichment capacity in the U.S. We must provide adequate support to assure that they continue to be maintained in good working order. The capital investment in diffusion plants is a sunk cost; the out-of-pocket cost of separative work at $60/SWU is attractive. In addition, there are good arguments for using these high-power-consuming plants as "flywheels" from which power may be drawn when it is badly needed elsewhere. Only with sufficient flexibility in power contracts can the diffusion plants respond to the needs of current stockpile demands, future delivery requirements, and load leveling of the power suppliers.

Gas Centrifuge Enrichment Plant. The gas centrifuge technology has been demonstrated as ready for production use. I believe we should proceed without hesitation with the GECP at Portsmouth, with the specific goal of having 2.2 million SWU/yr on line in 1988 and plans for completion of 8.8 million SWU/yr by 1993. I think this makes good sense in several regards:

- It is the only way we can preserve our option to build more enriching capacity for the next decade.

- It is the most effective and efficient way to meet the demands for separative work, domestic and foreign.

- Delay would introduce an excessive risk of not having the essential industrial participation for the project at some later time.

- Deferral of the only new enrichment capacity program would further hurt the image, already in need of improvement, of the U.S. as a dependable, long-term supplier to the rest of the world. The low boundary of my demand uncertainty might become a self-fulfilling prophecy.

- Further delay of new U.S. enrichment capacity would give greater encouragement to more foreign plants and development of new processes by more countries.

- As a practical matter, the availability of full power for the gaseous diffusion plants over the next 10 to 15 years is highly uncertain. The recent deferral in TVA power plant construction and other supplier systems underscores this uncertainty. This could force us to produce separative work some other way. The gas centrifuge process is the only alternative we have ready for commercial use now, and it is a low-power-consuming enrichment process.

So I think we should move ahead forcefully with the production centrifuge programs as well as with the work we have going on to develop improved and advanced machines. The centrifuge technology today is the best technology which is ready for full-scale production and has the potential for being substantially improved.

Advanced Uranium Enrichment Technologies. Decisions for supplying contracts for separative work into the 1990's will necessarily hinge on trade-offs between diffusion and centrifuge capacities; nevertheless, I believe that during this same period we should vigorously pursue advanced technologies. Whenever it appears to the U.S. enrichment community that one of the present AIS technologies or some alternative reaches the point where the next step in evolution from conception to production application has been reached, I believe that the decision should then be made to move ahead to the next step, depending on the overall economics and strategic needs of the U.S. enrichment business. In DOE's AIS program, it will be the mid-1980's before it will be possible to build an integrated development module of sufficient capacity and configuration to permit a valid assessment of the readiness and potential of that advanced technology for production use. Therefore, I do not believe it would be responsible to offer the promise of the advanced technology as a substitute for proceeding with the GCEP. This conviction in no way detracts from my enthusiasm in and optimism about our current AIS technologies.

In this regard, let me say that technology leadership is only a temporary advantage. We enjoyed clear world leadership in gaseous diffusion for 20 years, but France has about caught up with us now. We have had clear leadership in gas centrifuge technology for ten years, but Japan and Urenco are pressing us now with development programs at least as strong as the one which brought us where we are today. The competition in the field of advanced processes is very tough right now, with several large national programs under way. The practical value of technology leadership depends, however, on whether and how it is exploited. It is evident, however, that the U.S. should maintain a world leadership position in enrichment technology so that we are able to compete in the world market and have a beneficial influence on nuclear power fuel cycle developments throughout the world.

SUMMARY

To sum up, I believe that the basic DOE program on uranium enrichment--spanning diffusion plant operation, GCEP construction, and advanced process development--is correct in its main elements. We need a balanced, effective enrichment plan that is broad enough to accommodate the large uncertainties facing us. My specific recommendations are:

1. Maintain viability of the U.S. diffusion plants to assure meeting enrichment demands of the next decade.

2. Recognize the probability of the low availability of power for the gaseous diffusion plants in the near term, but maintain the option for long-term contracts for design-level electrical power.

3. Proceed without hesitation on construction of 2.2 million SWU/yr GCEP capacity to be available on stream by 1988 with plans for completion of 8.8 million SWU/yr in 1993.

4. Move ahead vigorously with R&D on the current AIS technologies with emphasis on fielding a development module for one or more technologies by the mid-1980's.

5. Continue the analytical evaluation (and testing where justified) of other proposed enrichment technologies.

6. Pursue realistic safeguards and proliferation goals.

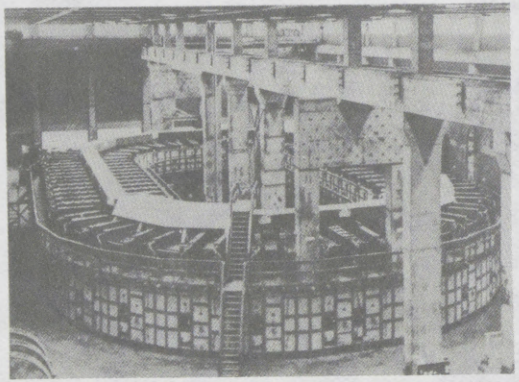
7. Continue aggressive marketing of uranium enrichment services overseas.

8. Pursue initiatives to structure U.S. enrichment activities to provide more standard business management flexibility.

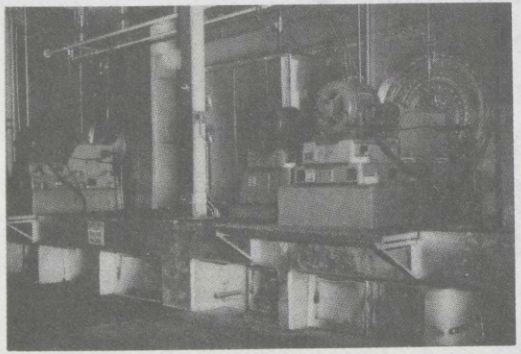
I believe that these actions will serve well our purpose of protecting options in uranium enrichment in order to support our own energy program and to offer a more coherent and more influential posture in the international arena. We are indeed fortunate that the enrichment portion of the fuel cycle is such a large potential asset to us. Enrichment is a business in which we can attain our international objectives and generate revenues at the same time. At the present time, we are still rich with options in enrichment and should exploit these for the benefit of the country.

I would be pleased to respond to any questions you might have.

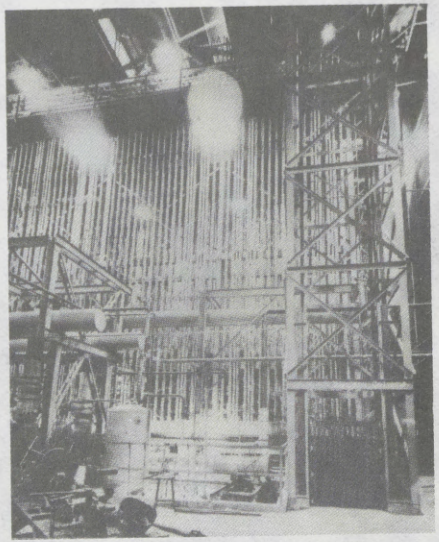
EARLY ENRICHMENT PLANTS AT OAK RIDGE



ELECTROMAGNETIC (CALUTRON) PROCESS (1944)



GASEOUS DIFFUSION PROCESS (1945)



THERMAL DIFFUSION PROCESS (1945)

CHART 1

FACTORS IN SELECTION OF PRODUCTION URANIUM ENRICHMENT PROCESSES

- SEPARATION FACTOR PER STAGE
- THROUGHPUT PER STAGE
- IN-PROCESS INVENTORY
- ENERGY REQUIREMENT
- CAPITAL COSTS
- OPERATING COSTS

TRADE-OFFS/BALANCES AMONG FACTORS IS REQUIRED

CHART 2

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TYPICAL EVOLUTION OF THE PRODUCTION URANIUM ENRICHMENT PROCESS

- IDEA STAGE
  - CONCEPT FEASIBILITY
- PROOF OF PRINCIPLE PHASE
  - SCIENTIFIC FEASIBILITY
- PROOF OF PROCESS PHASE
  - ENGINEERING FEASIBILITY
- PROOF OF VALUE PHASE
  - ECONOMIC FEASIBILITY

CHART 3

OVERVIEW OF UNITED STATES ENRICHMENT PROJECTS

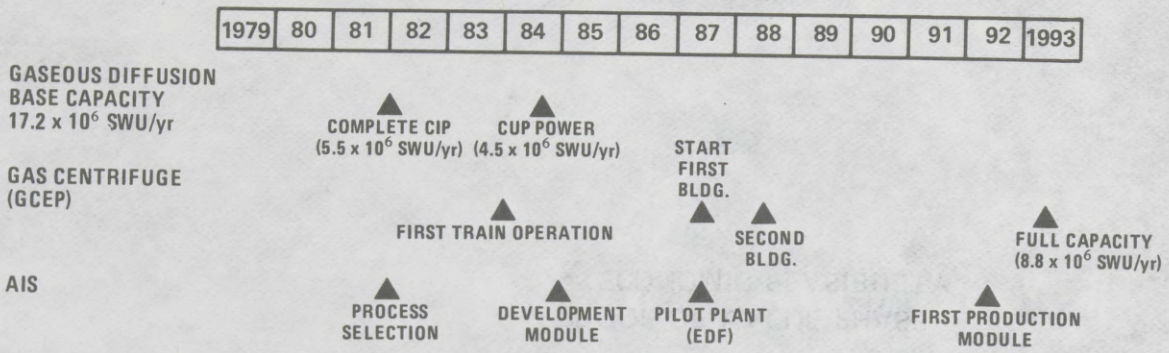


CHART 4

OVERVIEW OF NON-UNITED STATES ENRICHMENT PROJECTS

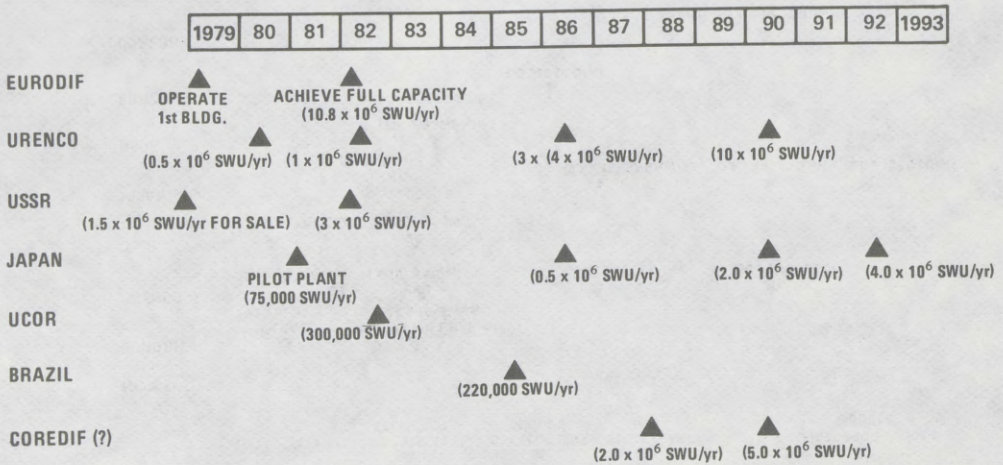


CHART 5

WORLD OVERVIEW OF ENRICHMENT PROJECTS

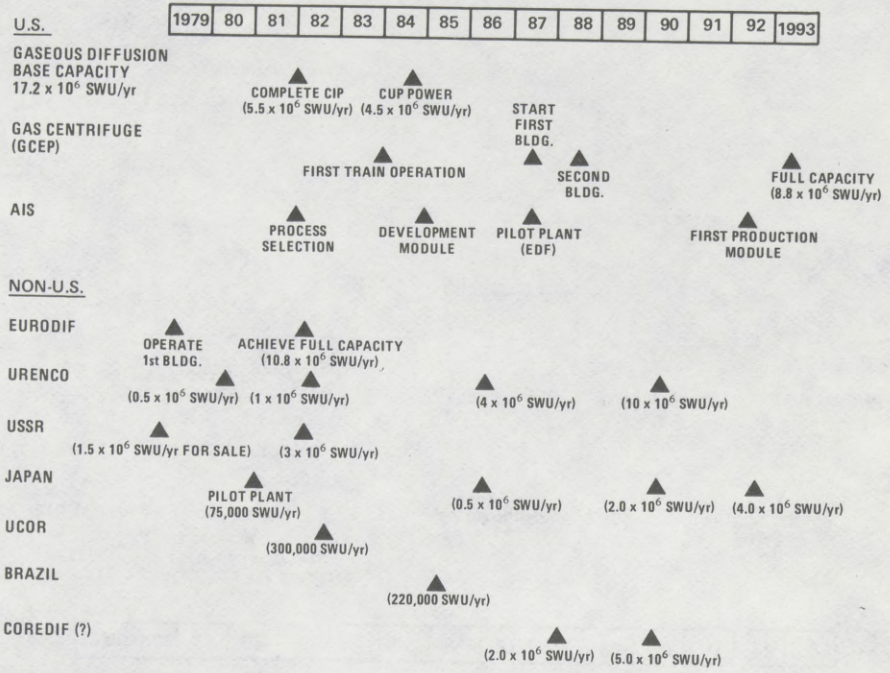


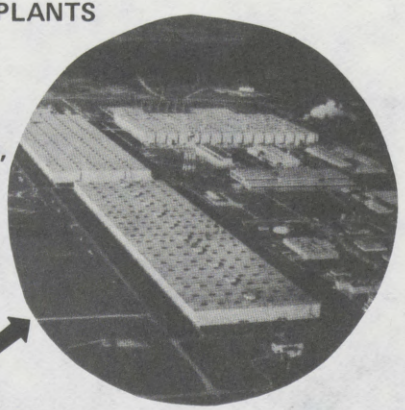
CHART 6

DOE GASEOUS DIFFUSION PLANTS



Paducah, Kentucky

Portsmouth, Ohio







Oak Ridge, Tennessee

CHART 7

THE INTERIOR OF AN IMPROVED GASEOUS DIFFUSION CELL

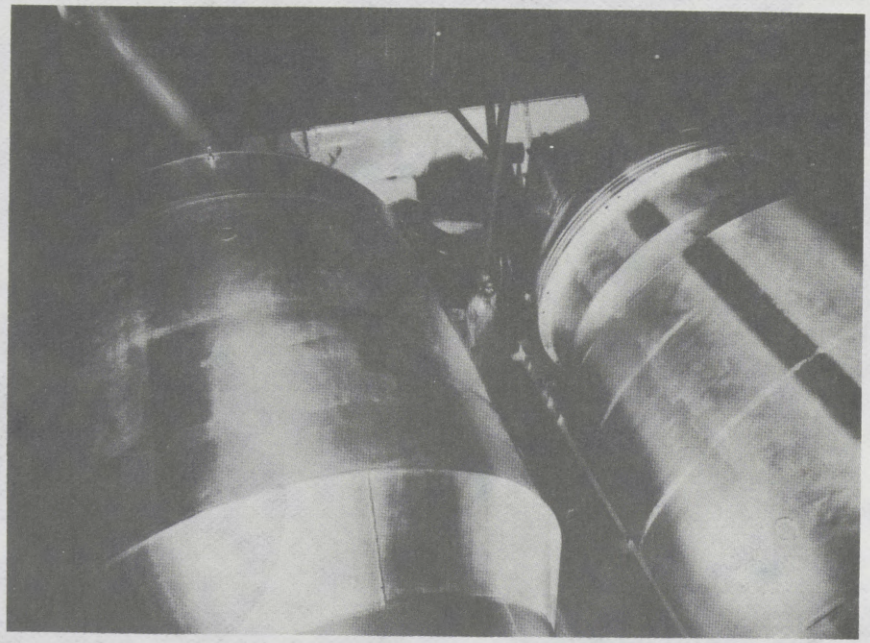


CHART 8

EURODIF GASEOUS DIFFUSION PLANT AT TRICASTIN

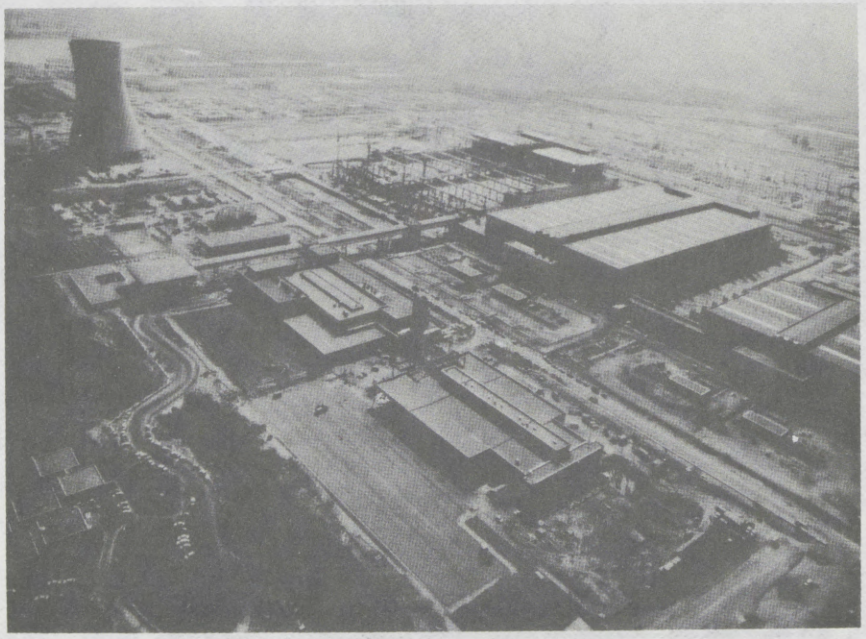
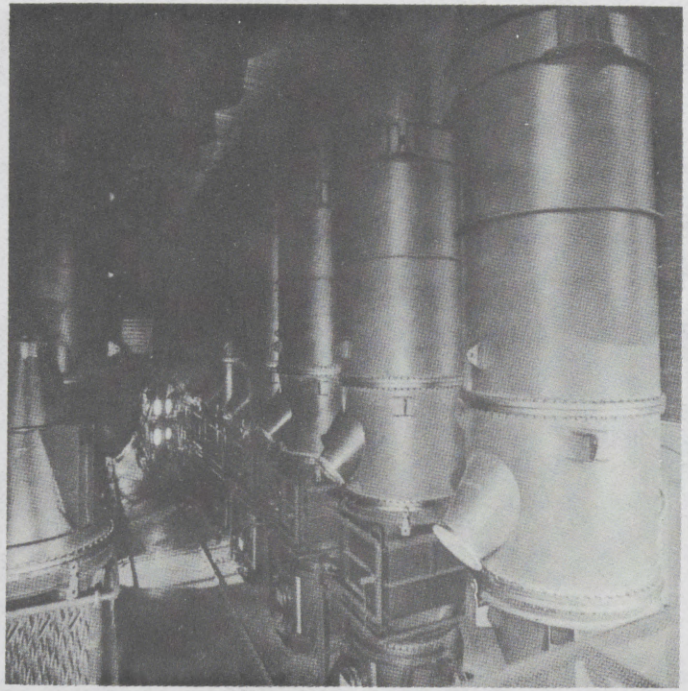


CHART 9

EURODIF DIFFUSION STAGES AND STAGE COMPONENTS



From Eurodif/76 (a brochure published by Eurodif, 116 Avenue Aristide-Briand, 92220 Bagneux (France), June 1977

CHART 10

PORTSMOUTH DIFFUSION AND CENTRIFUGE ENRICHMENT PLANTS

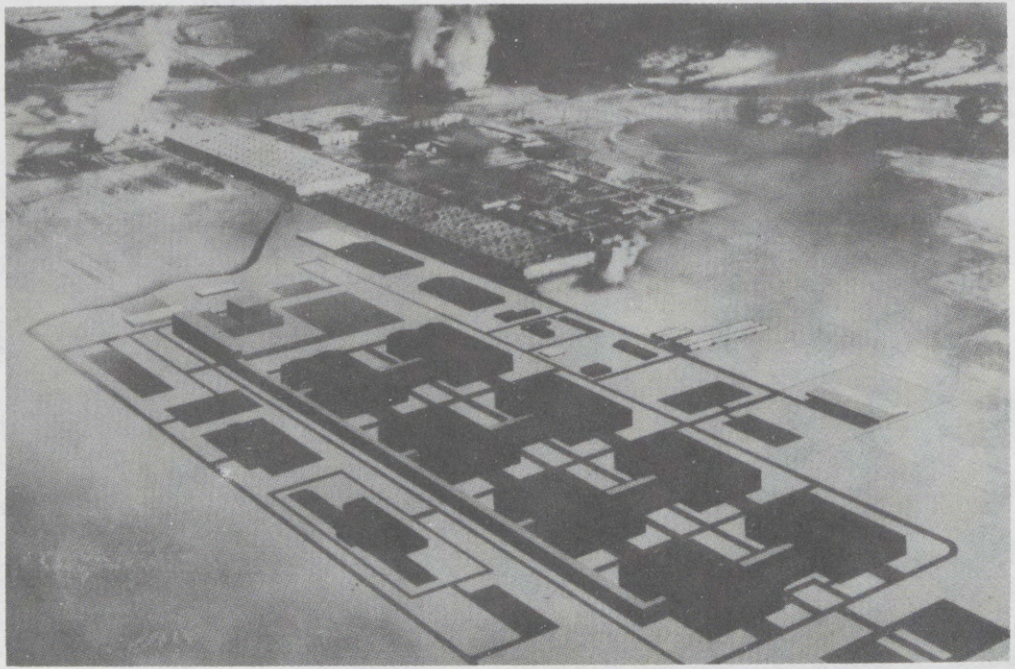
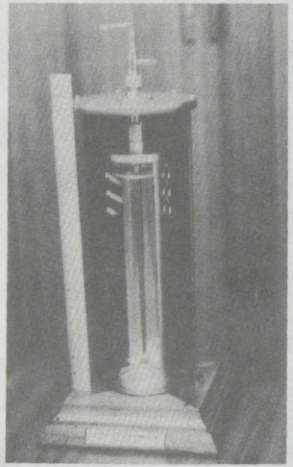
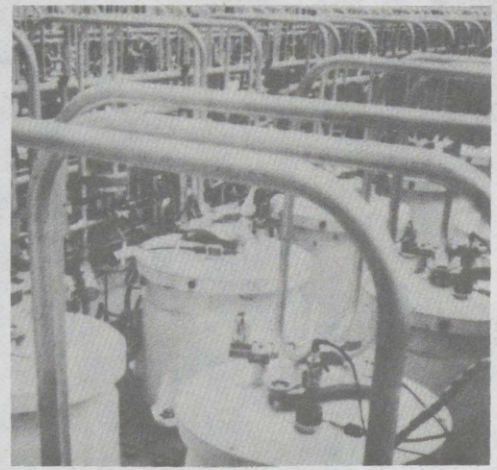


CHART 11

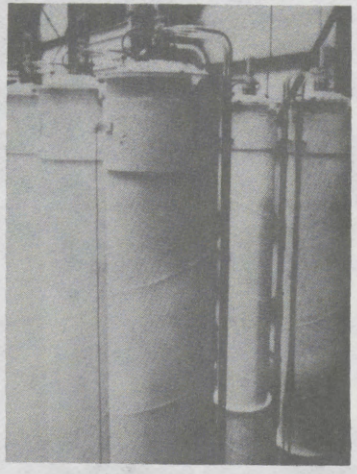
UNITED STATES GAS CENTRIFUGES



1958



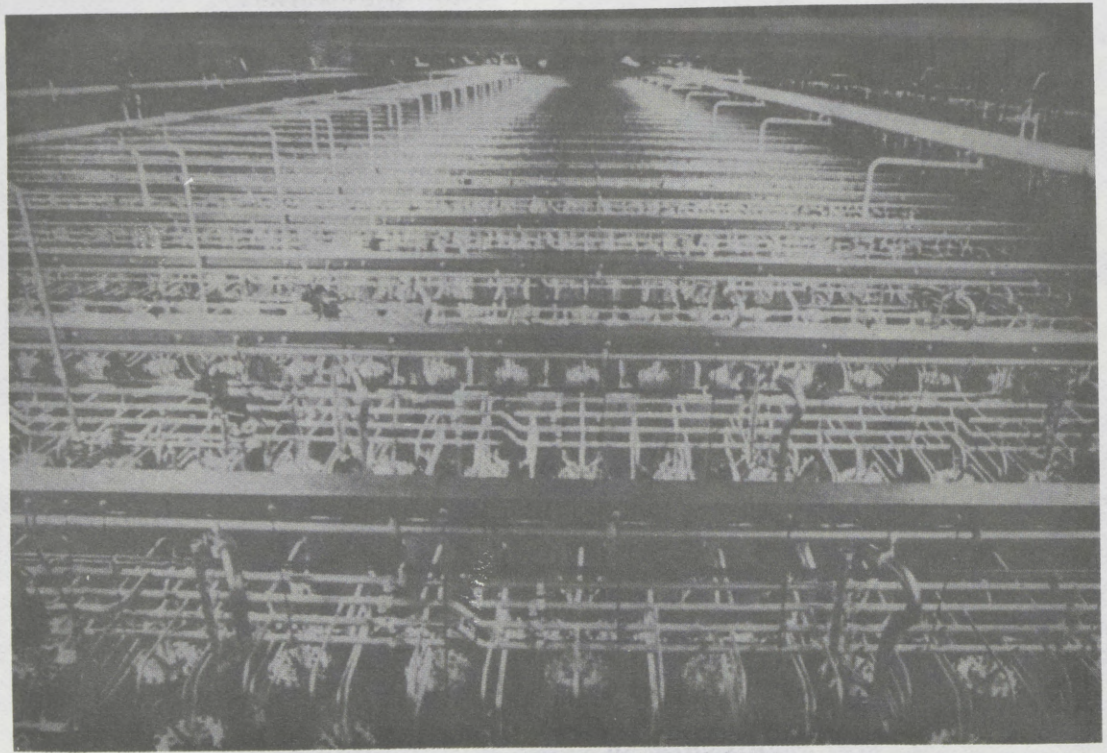
1975



1978

CHART 12

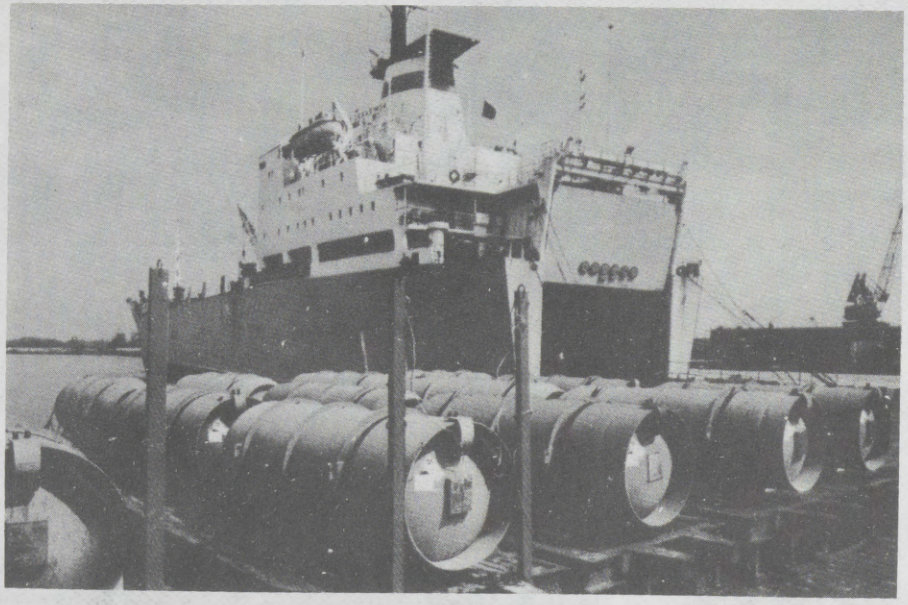
GERMAN GAS CENTRIFUGES AT ALMELO



From *Urenco-Centec* (a brochure published by Urenco Limited, 40 West Street, Marlow, Buckinghamshire, England), 1975.

CHART 13

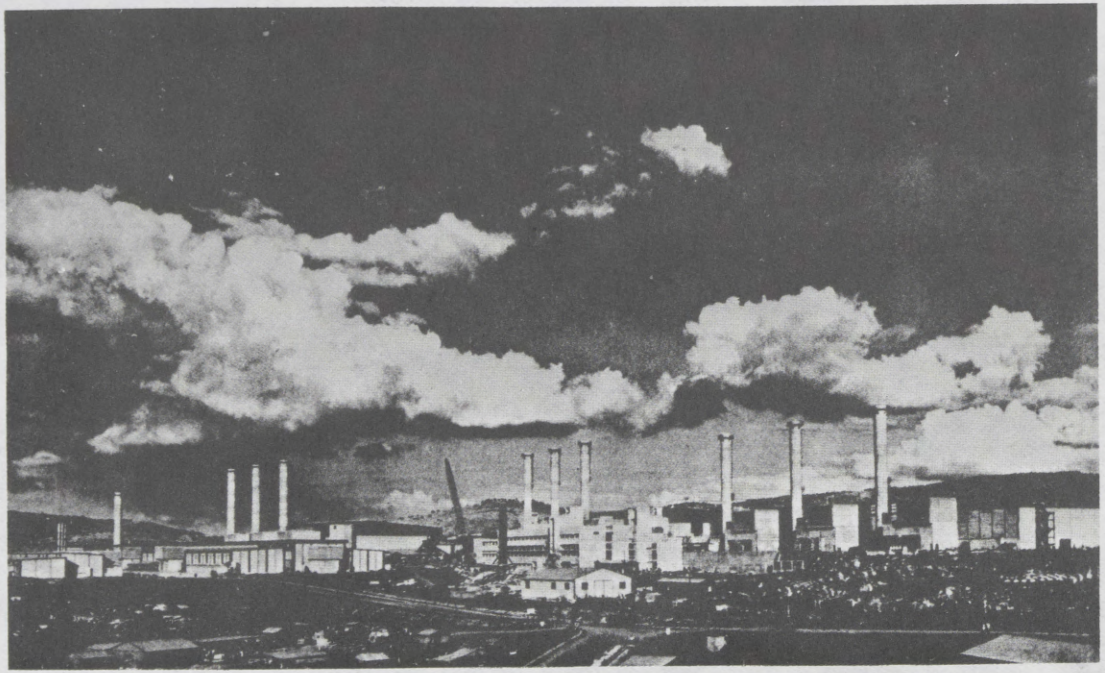
RUSSIAN URANIUM



NUKEM Market Report (March, 1979)

CHART 14

SOUTH AFRICAN PILOT PLANT AT VALINDABA



From European Nuclear Conference, 1st Paris, 1975. *Nuclear Energy Maturity,* New York, Pergamon Press, 1976.
Reprinted with permission from Pergamon Press, Inc.; Elmsford, New York.

CHART 15

U. S. DEMANDS FOR ENRICHMENT SERVICE AND AREA OF UNCERTAINTY

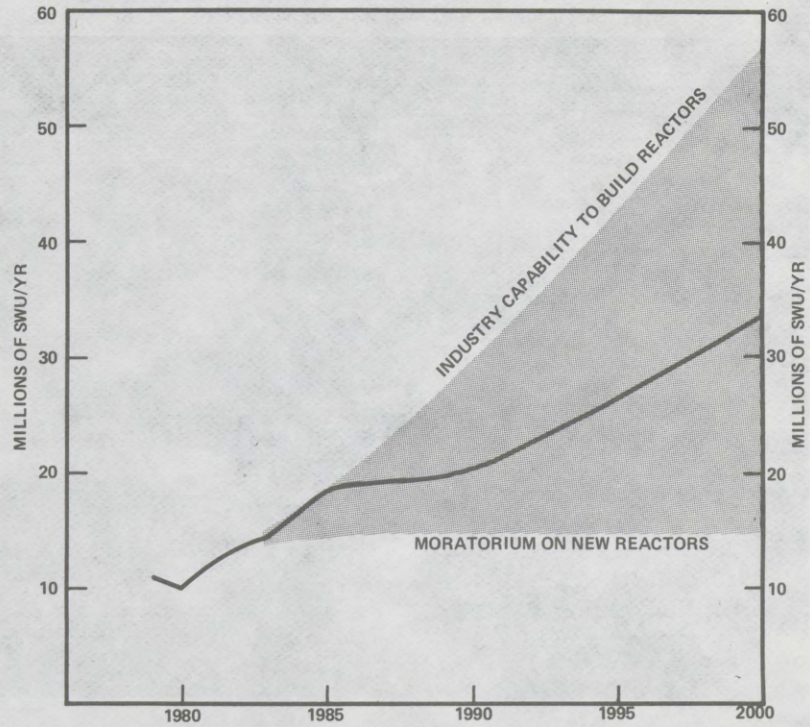


CHART 16

FOREIGN DEMANDS FOR U.S. ENRICHMENT SERVICE AND AREA OF UNCERTAINTY

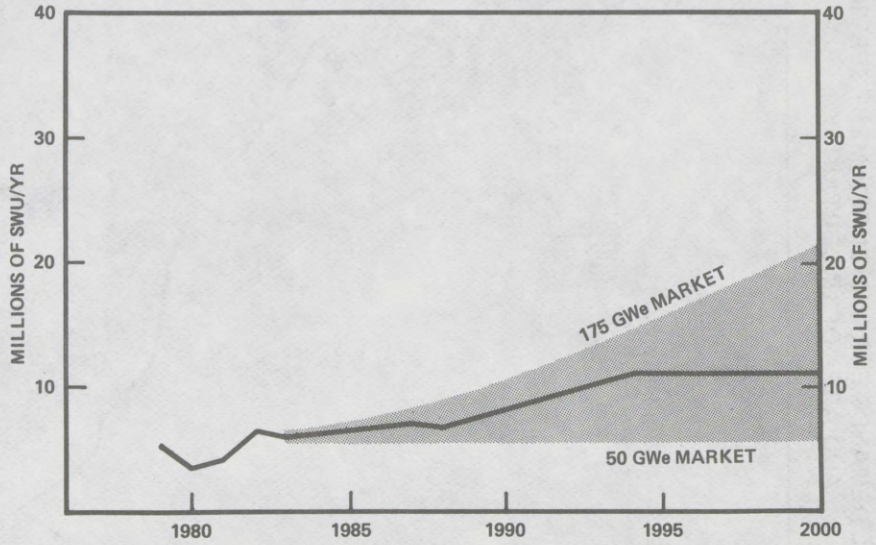


CHART 17

TOTAL DEMANDS FOR U. S. ENRICHMENT SERVICE AND AREA OF UNCERTAINTY

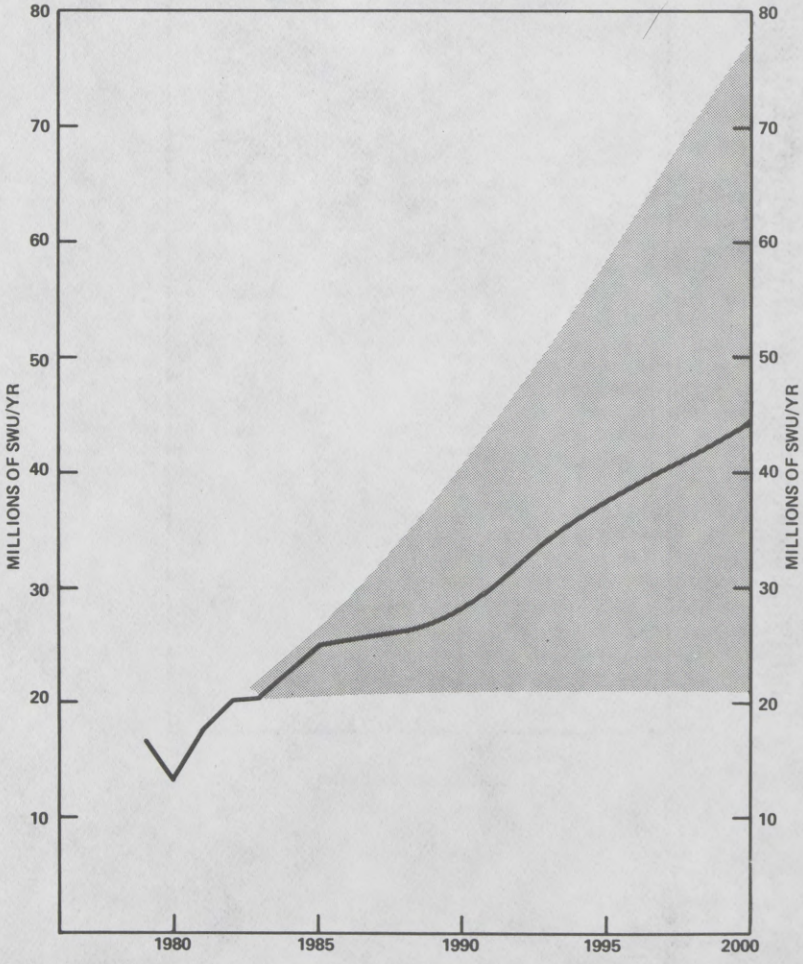


CHART 18

U. S. CAPABILITY VERSUS TOTAL DEMANDS FOR U. S. ENRICHMENT SERVICE

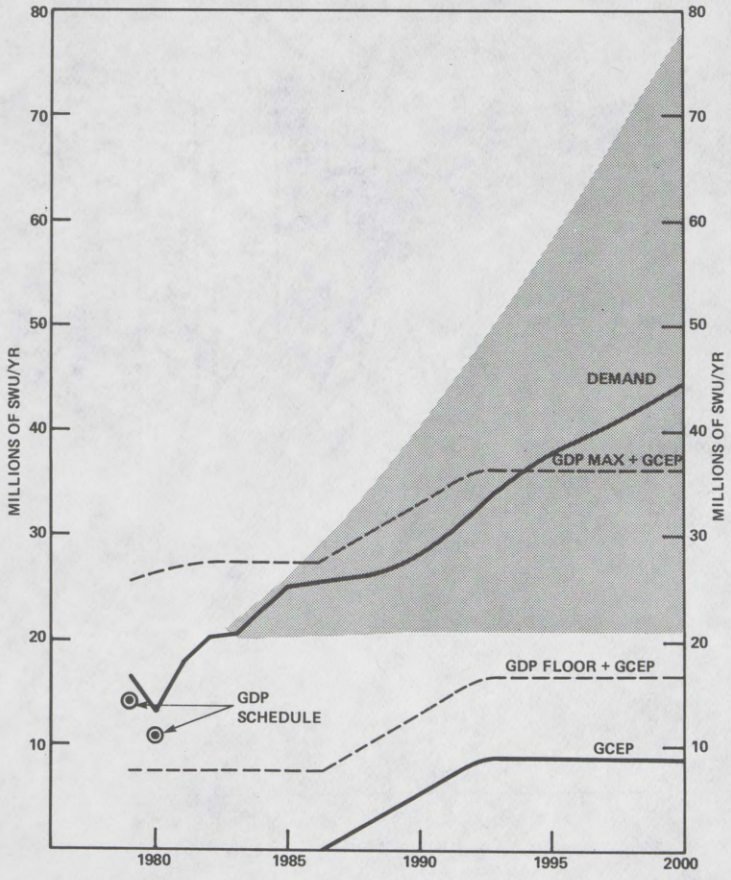


CHART 19

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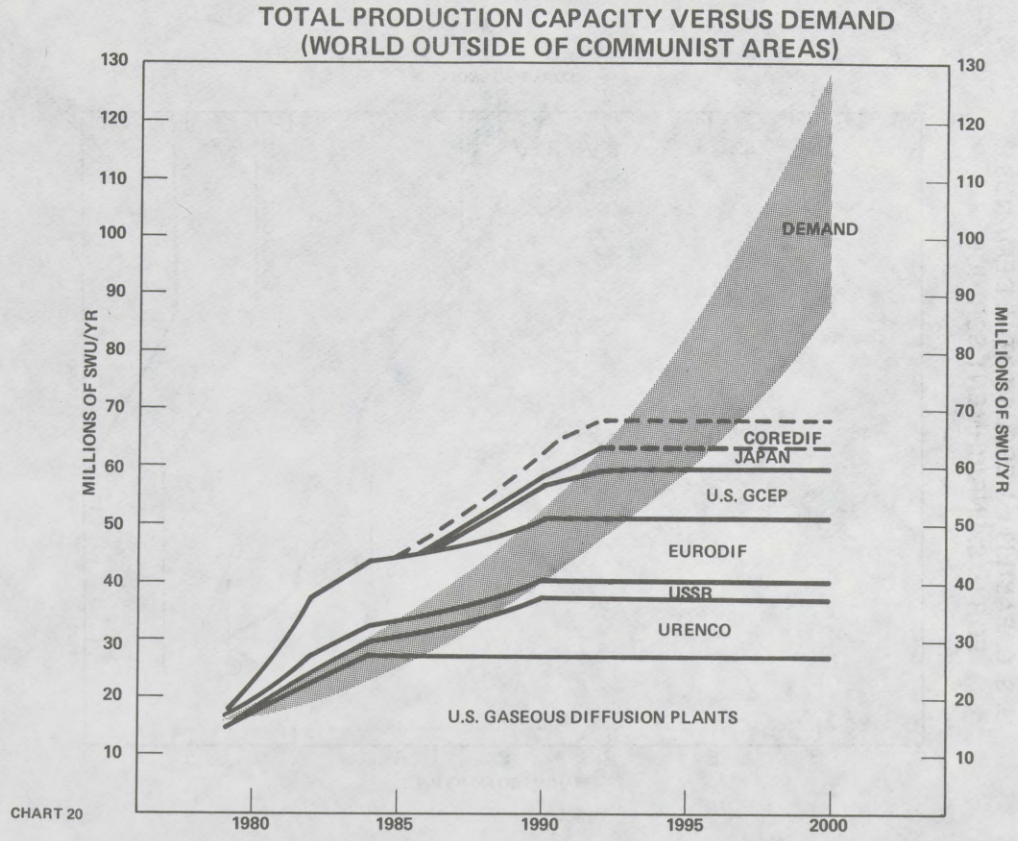
TOTAL PRODUCTION CAPACITY VERSUS DEMAND
(WORLD OUTSIDE OF COMMUNIST AREAS)
MILLIONS OF SWU/YR
MILLIONS OF SWU/YR
130
120
110
100
90
80
70
60
50
40
30
20
10
1980
1985
1990
1995
2000
DEMAND
COREDIF
JAPAN
U.S. GCEP
EURODIF
USSR
URENCO
U.S. GASEOUS DIFFUSION PLANTS

CHART 20

GASEOUS DIFFUSION PLANT RELIABILITY

COMPONENT	MEAN TIME BETWEEN FAILURES (YEARS)	REPLACEMENTS PER YEAR (%)
COMPRESSORS:		
AXIAL FLOW	30	3
CENTRIFUGAL	50	2
DIFFUSERS	300	0.3
MOTORS	60	1.7
SHAFT SEALS	9	11
BLOCK VALVES	100	1
CONTROL VALVES	250	0.4
GAS COOLERS	400	0.2
COOLANT CONDENSERS	60	1.7

CHART 21

GAS CENTRIFUGE PROCESS IS READY FOR COMMERCIAL USE

- HIGHLY SUCCESSFUL R&D PROGRAM UNDERWAY
- ABOUT $320 MILLION SPENT ON R&D
- ENGINEERING DESIGN AND OPTIMIZATION FAR ADVANCED
- INDUSTRY HAS BEEN ACTIVELY INVOLVED FOR 7 YEARS
  - FOUR COMPANIES HAVE MANUFACTURED PRODUCTION CENTRIFUGE MACHINES
  - ABOUT $100 MILLION PRIVATE INDUSTRY FUNDS INVESTED
- GCEP CENTRIFUGE MACHINE SUPPLIERS SELECTED BY D O E
- CAPACITY EXPANSION ECONOMICAL IN SMALL INCREMENTS

CHART 22

COMPARISON OF SOME ENRICHMENT PROCESSES ON BASIS OF SOME REPORTED ENERGY REQUIREMENTS

ENRICHMENT PROCESS	MILLIONS SWU/yr	KWHR/SWU	P.U.I. SWU/MWd
GASEOUS DIFFUSION			
DOE – PRE-CIP PLANT	17.2	3100	7.7
– CIP	5.75	0	
– CUP	4.75	2400	10.0
– CIP/CUP	10.5	1085	22.1
– IMPROVED PLANT	27.7	2340	10.3
EURODIF	10.8	2520*	9.5
UEA	9	2270*	10.6
GAS NOZZLE – (BECKER PROCESS)		4000* (OVERALL)	6.0
FIXED WALL CENTRIFUGE – (UCOR)	5	3500* (OVERALL)	6.9
GAS CENTRIFUGE (U.S.)	9	135	180

*QUOTED BY BENEDICT AT THE EUROPEAN NUCLEAR CONFERENCE, PARIS, APRIL 1975.

CHART 23

ENERGY SAVINGS WITH CENTRIFUGE PROCESS (8.8 MILLION SWU/YR PLANTS)

	GASEOUS DIFFUSION	GAS CENTRIFUGE
MWe REQUIRED TO OPERATE	2,340	135
1000 MWe POWER PLANTS NEEDED TO SERVICE	4	1/10

ENERGY AVOIDANCE/yr – 19.6 BILLION kWhrs

- POWER FOR 425,000 HOMES
- EQUIVALENT TO 4 LARGEST CITIES IN TENNESSEE COMBINED

EQUIVALENT "SAVINGS" OVER 25 YEARS

- 160 MILLION tons OF COAL
- 710 MILLION BARRELS OF OIL

CHART 24

FEATURES WHICH IN COMBINATION DETERMINE THE PRODUCTION ATTRACTIVENESS OF AN ENRICHMENT PROCESS

	GASEOUS DIFFUSION	GAS CENTRIFUGE	AERODYNAMIC*	CHEMICAL EXCHANGE*	LASER/PLASMA*
SEPARATION FACTOR (THE HIGHER THE BETTER)	REFERENCE	BETTER	COMPARABLE	POORER	BETTER
DEVICE THROUGHPUT (THE HIGHER THE BETTER)	REFERENCE	POORER	COMPARABLE	COMPARABLE	POORER
IN-PROCESS INVENTORY (THE LOWER THE BETTER)	REFERENCE	BETTER	BETTER	POORER	BETTER
ENERGY REQUIREMENT (THE LOWER THE BETTER)	REFERENCE	BETTER	COMPARABLE-POORER	BETTER-COMPARABLE	BETTER
CAPITAL COSTS (THE LOWER THE BETTER)	REFERENCE	POORER	COMPARABLE	COMPARABLE	BETTER

*BASED ON ESTIMATES OF PROCESS POTENTIAL

CHART 25

ENRICHMENT TECHNOLOGY, PROLIFERATION

MISCONCEPTIONS HAVE CLOUDED THE PROLIFERATION ISSUE -- THE FACTS ARE THAT:

- ANY POWER REACTOR FUEL ENRICHMENT PROCESS REPRESENTS A PROLIFERATION RISK
- TECHNOLOGY DOES EVOLVE -- EVEN TODAY'S COMPLEX ADVANCED PROCESSES MAY BE A PROLIFERATION THREAT TOMORROW
- URANIUM ENRICHMENT TECHNOLOGY MAY POSE A PROLIFERATION RISK COMPARABLE TO PLUTONIUM

CHART 26

BALANCED APPROACH TO REDUCE TECHNOLOGY PROLIFERATION

REDUCE THE MOTIVATION AND INCENTIVES TO PROLIFERATION

- DEPENDABLE, ECONOMICAL SOURCE OF NUCLEAR FUEL
- COOPERATIVE INTERNATIONAL AGREEMENTS

REDUCE THE OPPORTUNITY TO PROLIFERATE

- JOINT EFFORTS BY ALL ENRICHMENT SUPPLIERS
  - SECURITY
  - CLASSIFICATION
  - EXPORT CONTROLS
  - SAFEGUARDS
  - SANCTIONS

CHART 27

CONCLUSIONS

DIFFUSION

- MAINTAIN VIABILITY OF DIFFUSION CAPACITY
- MAINTAIN OPTION TO GO TO PLANT DESIGN POWER LEVELS

CENTRIFUGE

- PROCEED WITHOUT HESITATION ON PRESENT GCEP SCHEDULE

AIS

- MOVE AHEAD VIGOROUSLY WITH THE AIS PROGRAM

CONCLUSIONS (CONTINUED)

GENERAL

- CONTINUE ANALYTICAL EVALUATION OF OTHER TECHNOLOGIES
- PURSUE REALISTIC PROLIFERATION AND SAFEGUARDS GOALS
- CONTINUE AGGRESSIVE MARKETING OF URANIUM ENRICHMENT SERVICES
- PROVIDE MORE BUSINESS MANAGEMENT FLEXIBILITY FOR U.S. ENRICHMENT ACTIVITIES

STATEMENT OF PAUL R. VANSTRUM

Mr. VANSTRUM. Thank you.

Since you have heard a great deal about the U.S. program already, I would like to move to my first chart in which I try to summarize not just the U.S. program with its major elements of gaseous diffusion, gas centrifuge, and the new advanced methods, but also try to show the important programs overseas.

[Chart 6 was displayed.]

There is a wide range of activity in terms of a number of other nations, but also activities which spread out over the next two decades. Examining these plans more closely, it is of interest to find that in each country there seems to be a favoriate candidate process. There is no universal interest in just one enrichment technology.

Eurodif, a multinational gaseous diffusion project in Tricastin, France, is financed by France, Italy, Spain, Belgium, and Iran, and is in the construction completion and start-up phase. Incidentally, power for the plant will come from nuclear reactors also under construction at the Tricastin site. By 1982, Eurodif will have the capacity on line of 10.8 million separative work units per year, which is over one-third of the installed U.S. capacity in 1982. Urenco, a multinational gas centrifuge project sponsored by the United Kingdom, Federal Republic of Germany, and the Netherlands, is in commercial operation. It is presently a much smaller project than Eurodif, but Urenco is steadily expanding its capacity. Present schedules are for 1 million separative work units per year by 1982, and Urenco has talked about having up to 10 million separative work units per year by 1990. Some of Urenco's customers in countries which are Urenco sponsors have recently canceled U.S. enrichment contracts. The U.S.S.R., shown here, is presently a significant supplier to the Western European market in particular, with about a 3-million separative work units per year business expected in the early 1980's.

Mr. MCCORMACK. It does not show the total Russian production. Do we not know what that is?

Mr. VANSTRUM. I do not know precisely what it is, but it is obviously substantially greater than the 3-million separative work units per year. It has been quoted in the literature as being on the order of 10 million separative work units per year.

Mr. MCCORMACK. Thank you.

Mr. VANSTRUM. The Japanese have an aggressive gas centrifuge program and expect to achieve significant capacities. The projects being built in South Africa and those being discussed by Brazil both employ aerodynamic processes and are of relatively low capacity from a commercial standpoint. I must emphasize that these are just the enrichment plant projects which are either underway or being actively considered right now. Many nations throughout the world are also engaged in research and development of uranium enrichment by diffusion, centrifuge, aerodynamic, laser, electromagnetic, chemical, and other techniques.

[Chart 20 was displayed.]

In my next chart, I show these suppliers with their increasing capacity with time against the curves of free world demand. It seems likely that if all these plans materialize on the schedules indicated there could be production capacity exceeding demand through the 1980's unless some ongoing programs are cut back. By the early to

mid-1990's, however, there seems to be a need for at least some additional capacity, with several suppliers having a base which expands competition. The longer term picture, however, is very fluid and very uncertain.

[Chart 18 was displayed.]

Next, I would like to comment on U.S. prospects in this free world market. If I combine estimates for ranges of demand for U.S. supplied separative work for our domestic and foreign customers, I get the picture shown in my next chart. This has a heavy line representing a reasonable projection of today's demand. The white area indicates the large uncertainty which of course increases as we look further into the future. This uncertainty, both on the high side and the low side, must be taken into account in formulating meaningful strategies for uranium enrichment.

[Chart 19 was displayed.]

My next chart presents our production capability against this demand picture. It appears at first glance that we will have ample gaseous diffusion capacity to satisfy our demands through the 1980's and that a combination of fully powered gaseous diffusion and centrifuge plant could cover the likely demand shown by the heavy curve until the early 1990's. However, gaseous diffusion production, as distinct from capacity, may be severely limited by deliberate or unavoidable shortfalls in electrical energy. As a matter of fact, the points indicated below the demand curve indicate that inventory is being withdrawn from the stockpile for the 2 years indicated, and that is the situation we are facing today. The ability to absorb these shortfalls is indeed highly desirable as has been demonstrated on numerous prior occasions when the gaseous diffusion complex has been used as a major flywheel for the electric supply systems which power it. Therefore, I think we need to both proceed with the centrifuge plant and to preserve the option to obtain near-design power for the diffusion plants in the longer term.

Mr. McCormack. Excuse me. This total excludes any recycling fuel, doesn't it? This is all based on once through use of fuel and no use of either plutonium or uranium 233.

Mr. Vanstrum. That is correct. I really don't want to attach a great deal of precision to the projections. Rather, I would like to point out the wide range of possible demands that we might have to meet and encourage planning that would enable us to meet this wide range of plants. But your point is a good one.

Mr. McCormack. Thank you.

Mr. Vanstrum. Note that additional separative capacity will likely be required in the mid-1990's, even assuming fully powered diffusion plants and full centrifuge plant operation. If we find it not prudent to fully power the diffusion plants, we will need additional capacity, perhaps in the early 1990's.

The level of our technology is one of the important considerations in evaluating our ability to compete in the world market. You have heard some thoughts on this technology already, but I would like to summarize my thoughts in this area.

U.S. diffusion plants are very efficient, proven highly reliable, and, in my opinion, are the best in the world. Although they are large power consumers in comparison to the centrifuge, they are safe, robust, dependable plants, using a well understood technology. They have supplied most of the world's separative work to date and will supply half of what the free world requires between now and the year 2000.

The centrifuge is the only other technology ready now for production use, and I believe the United States is a clear leader in this technology also. Our program has been in the engineering and demonstration phase since 1970. The centrifuge process is a low power consumer, is proven ready for production application, it is already cost effective, and yet we believe there are still many opportunities for improvement. After the centrifuge plant is built, the out-of-pocket operating cost will be a very attractive $20 per separate work unit.

On advanced methods, we have three promising processes now under study; and with the continuing strong programs by outstanding, energetic, and creative organizations, I have great confidence that we can continue to be out front in the uranium enrichment technology.

We can go into the marketplace knowing that our technology will enable sales arrangements mutually beneficial to the United States and its customers.

Let me comment briefly on the proliferation issue. One has only to witness the Pakistani centrifuge effort and South African aerodynamic effort to recognize the seriousness of this problem. Proliferation has been a concern of ours since the inception of the enrichment business. I feel there are some misconceptions about the proliferation issue as it applies specifically to uranium enrichment, and I would like to share my views in the next chart.

[Chart 26 was displayed.]

The first of the misconceptions indicated here is the frequently overstated idea that there are overwhelming differences in proliferation potential among the available technologies. I believe it is important to recognize that any technology being developed for enrichment of uranium for power reactor fuel constitutes a proliferation risk. Even improved chemical exchange methods, such as those the French are talking about, should not be entirely ruled out at this time. The decision of which technology to use is not just a technical one, but also very much an individualized national consideration.

The second erroneous idea is that of technology constancy. Enrichment technology is very dynamic. Today, it appears that the laser and plasma processes are so technologically complex that they will not pose a proliferation threat, especially from the less-advanced countries. In the future, however, especially if we have success in AIS process development and demonstration, this picture could change markedly.

The third misconception is the idea that enrichment poses substantially less of a proliferation risk than the fuel reprocessing route. Clearly, the national policy on discouraging nuclear proliferation has focused predominately on reprocessing in recent years; and, of course, enrichment and reprocessing do represent different types of proliferation concerns. I would urge a more balanced position in evaluating proliferation aspects of enrichment and reprocessing technologies. In this regard, the serious proliferation questions surrounding the advanced processes, in my judgment, deal not with precise technical details right now, but with the future developments. As the advanced processes succeed and introduce less expensive separative work into the market, it is inevitable that the U_{235} route will become correspondingly more attractive vis-a-vis the reprocessing route.

At one point, the United States was the unchallenged reliable enrichment supplier to the entire free world. Today, enrichment tech-

nology has been proliferated on a wide scale. To some extent, this trend has been in response to U.S. actions such as closed order books and, more recently, to our own nonproliferation initiatives, which have not always had the effect we intended. The issue before us today is no longer how to prevent any proliferation of enrichment technology. Some has already occurred. The issue is to prevent further spread of this technology, to the extent we can, and to take whatever steps we can to preclude the use of this technology in weapons production. The best way to deal with this issue of enrichment proliferation risk, in our opinion, is:

[Chart 27 was displayed.]

First: To reduce the incentive to proliferate by establishing the United States as a dependable, low-cost supplier of enriched uranium.

Second: To work jointly with other suppliers to reduce the opportunity to proliferate, using all our available tools like security, classification, export controls, and safeguards.

With regard to the issue of safeguards, as you are aware, the gas centrifuge plant will likely be made eligible for International Atomic Energy Agency safeguards inspection as a consequence of the U.S./IAEA agreement which is now before the Senate for ratification. We understand the importance of the policy of applying IAEA safeguards to U.S. facilities as a means of encouraging the widest international adherence to the nonproliferation treaty. We are, however, concerned about the potential risk of the dissemination of enrichment technologies as a byproduct of international inspection. I think it is imperative that the United States discourage the further spread of enrichment technologies, particularly the advanced technologies, including the classified gas centrifuge. The challenge is to develop techniques which afford adequate safeguards and which protect simultaneously against the dissemination of advanced technologies which would erode the ability of the United States to encourage nonproliferation policies worldwide.

In conclusion, I have addressed in my submitted paper some of the issues facing the U.S. enrichment business of today as well as issues involved in exploiting the attractive potential of the advanced uranium enrichment technologies. In drawing some conclusions as to what should be our course during the next few years, we all recognize that there are considerable uncertainties which must be taken into account in the market, in the actions of foreign enrichers, and in the area of new technologies. My conclusions must, of course, rest on some assumptions about the goals and objectives of the enrichment business for the United States. My perception of our U.S. enrichment objectives is covered in the paper; perhaps the two most important of these are:

First: That the United States wants to be recognized as a dependable, low-cost, long-term enrichment services supplier domestically and overseas. This can result in substantial economic benefits to the United States and reduced pressure to proliferate enrichment plants abroad.

Second: That the United States wants to be the world leader in enrichment technologies, not only because of the benefits this brings to the United States by providing and protecting options to use the cheapest and best process in tracking demands, but also so that we can know just what options other nations might have in using other technologies to enrich uranium.

Now, based on our review of the situation today and our view of the future, I offer the following conclusions. I believe the basic DOE program on uranium enrichment is correct in the main elements. We need a balanced enrichment plan, broad enough to accommodate the large uncertainties facing us in the future.

In regard to diffusion plants, the U.S. gaseous diffusion plants will supply about half of the U.S. and foreign separative work during the remainder of this century, and are the foundation of our enrichment capacity in the United States. We must provide adequate support to assure that they continue to be maintained in good working order. The capital investment in diffusion plants is a sunk cost; the out-of-pocket cost of separative work at $60 per separative work unit is attractive. In addition, there are good arguments for using these high-power-consuming plants as fly wheels from which power may be drawn when it is badly needed elsewhere. Only with sufficient flexibility in power contracts, so there is at least the option of going to plant design power levels, can the diffusion plants respond to the needs of current stockpile demands, future delivery requirements, and load leveling of the power suppliers.

With regard to the gas centrifuge enrichment plant, I believe we should proceed without hesitation with the centrifuge plant at Portsmouth, with the specific goal of having 2.2 million separative work units per year on line in 1988 and plans for completion of 8.8 million separate work units per year by 1993. I think this makes good sense in several regards:

It is the only realistic way we can preserve our option to build more enriching capacity for the next decade.

It is the most effective and efficient way of meeting the demands for separative work, domestic and foreign.

Delay would introduce an excessive risk of not having the essential industrial participation for the project at some later time.

Deferral of the only new enrichment capacity program would further hurt the image, already in need of improvement, of the United States as a dependable, long-term supplier to the rest of the world.

To delay U.S. enrichment capacity further would give greater encouragement to more foreign plants and development of new processes by more countries.

We may simply not be able to put the necessary power into our diffusion plants, forcing us to produce separative work some other way. The gas centrifuge process is the only alternative we have ready for production use now, and it is a low-power-consuming enrichment process.

In the case of the advanced uranium enrichment technologies, I believe that we should vigorously pursue advanced technologies. I believe whenever it appears to the U.S. enrichment community that one of the present AIS technologies, or some alternative, reaches the point where the next step in evolution from conception to production application has been reached, that the decision should then be made to move ahead to the next step, depending, of course, on the overall economics and strategic needs of the U.S. enrichment business. In DOE's AIS program, that next step is the development module, and I urge emphasizing that in our program planning.

We feel further it is important that we continue to watch science and engineering developments around the world and carry out our

analytical assessments of new technologies or ideas for enrichment processes. We want to stay on top of the field of enrichment methods and possibilities.

We want to help devise and to help pursue realistic approaches to reducing proliferation risk and develop effective safeguards without spreading technologies.

We endorse and urge the aggressive marketing of U.S. enrichment services. It is the best way to build credibility as a supplier and to reduce motivation for proliferation by others. It can be of substantial economic benefit to the United States and, if attractive terms and conditions can be offered, it will be of real benefit to our customers.

We endorse and encourage the pursuit of initiatives to enable the Government to manage the enrichment enterprise with more standard business management flexibility, in matters such as pricing, production planning, R. & D., and capital expenditures.

In summary, I believe that these generalized recommendations, together with my program related recommendations, will serve well our purpose of protecting options in uranium enrichment in order to support our own energy program and to offer a more coherent and more influential posture in the international arena. We are indeed fortunate that the enrichment portion of the fuel cycle is such a large potential asset to us. Enrichment is a business in which we can attain our international objectives and generate revenues at the same time. At the present time, we are still rich with options in enrichment, and should exploit these for the benefit of the country.

Thank you, and that is the end of my statement.

Mr. McCormack. Thank you, Mr. Vanstrum, for a truly special presentation. I am sure the other members of the committee and I very much agree with many of the points that you have made. I know I for one, as you went through your conclusions, found myself agreeing with each point that you made.

I have several questions here, and I am going to suggest that perhaps each member will have an opportunity to ask questions. Maybe we can go around the table a couple of times to give everybody a chance.

Let me start off with a couple of very quick ones. You didn't clearly say so, but you seemed to imply that there is no practical benefit to replacing existing diffusion plants with centrifuge plants or other advanced technologies, as far as you can see at the present time, that they must—the centrifuge and other advanced technologies—must supplement rather than replace the diffusion plants. Now, have you done any analysis on the economic trade-offs of simply replacing the diffusion plants with centrifuge plants?

Mr. Vanstrum. Yes, that is the kind of thing we do regularly. Of course, one has to get the total cost of separative work by the centrifuge or some alternative process below the out-of-pocket cost of separative work for gaseous diffusion before it becomes economically advantageous to do so. If one projects increasing cost of energy in the future, as we have seen in recent times, then one can come up with a point in time when the incremental cost of new centrifuge capacity will be below the operating costs of the ongoing gaseous diffusion plant. At that point, it would be advantageous to displace the diffusion process with the centrifuge. If one can come up with a process such as Bob Merriman described, in which the projected total

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cost of separative work is well below $60, then you might not have to wait so long. If you have that process well in hand, you can make the displacement whenever that point occurs. As we see it now, it will probably be sometime in the 1990's before we will have a process, either centrifuge or one of the advanced processes, with sufficiently better cost to replace gaseous diffusion. However, that is a real possibility sometime in the future.

Mr. McCormack. Will you continue to analyze this as an option, the possibility at some point or other, of recommending the diffusion plants themselves be replaced with new facilities?

Mr. Vanstrum. Whenever that is an attractive option, we would certainly recommend it, yes, sir.

Mr. McCormack. A rather peripheral question. As far as you can tell, is the laser isotope separation technology or the plasma technology clearly superior to any technology in view, any of the other technologies that have been explored around the world, in terms of efficiency of cost and so on?

Mr. Vanstrum. In my opinion, these particular advanced methods are better than any of the others, and that is why our program has concentrated in those areas. It remains to be seen if we can develop and engineer them as well as we seek to.

Mr. McCormack. You would not, at this time, advocate broadening the scope then of our development of those programs beyond the three that were presented today by Mr. Merriman?

Mr. Vanstrum. Not other than in an exploratory experimental and analytical evaluation way. As I mentioned, I think we should stay alert to new processes and new ideas and suggestions. We should always be careful to evaluate them and be sure we don't miss any good bets, but I see none on the horizon that warrant the large scale R. & D. efforts that we have on the AIS programs.

Mr. McCormack. OK. Is it not possible to construct enrichment facilities so that high enrichment is not possible without reconstruction or difficult physical modification?

Mr. Vanstrum. Well, it is certainly possible to design and construct enrichment plants that make it more difficult to go to higher enrichments. However, it doesn't give me very much comfort, because by the time you get to 3 percent enriched uranium, you have done about 60 percent of the separative work you need to go to weapons level material. So any proliferation of capability to produce 3 percent reactor fuel gives me an uneasy feeling about the capability that enricher would have for going to higher enrichments.

Mr. McCormack. Let me ask the question another way. If one built a facility designed exclusively for nuclear energy, 3 percent enrichment, and had an IAEA inspection and satellites inspection, would't that pretty much preclude the possibility of using it for higher enrichment?

Mr. Vanstrum. I think it depends on the process. I believe that if the enrichnent process involved is gaseous diffusion, that's a fairly good and fairly safe approach. However, if you are considering a process like the gas centrifuge and potentially the advanced isotope separation processes that have high separation factors, then with these processes the enricher has inherent capabilities to rearrange the plant to cover a large concentration range. One may have to undertake

some repiping, even some redesign and process modification, but relatively speaking, compared to building a plant in the first place, that is a rather minor change.

Mr. McCormack. It could be detected with good satellite surveillance?

Mr. Vanstrum. I think you would have to get the advice of the experts on satellites.

Mr. McCormack. OK, I won't push you on that. One other question.

Today, I take it that it is cheaper for a small nation to build a weapon using a small water cooled reactor with hot cells. Dr. Seaborg says that there are about 36 countries that can make nuclear weapons using this technology and it takes about 4 years and costs about $50 million. Assuming this is true, do you really envision a time when enrichment costs and technologies and difficulties will be so improved that enrichment will be an easier path to weapons than what is available today?

Mr. Vanstrum. I think it depends on circumstances in the country. Pakistan is a good example, They have apparently, as reported in the press, pursued both the enrichment and reprocessing routes, possibly neither one successfully yet, but their perception was that both offer reasonable opportunities for weapons level material.

Mr. McCormack. Thank you, Mr. Roth?

Mr. Roth. Thank you, Mr. Chairman. Mr. Vanstrum, why did Urenco cancel the U.S. contracts?

Mr. Vanstrum. I beg your pardon?

Mr. Roth. Why did the Urenco nations cancel our contracts?

Mr. Vanstrum. I really think the question should be directed to Bill Voigt. I was not involved in the contracts so I really do not know.

Mr. Voigt. There were two factors involved, Congressman, as I tried to indicate earlier. One was a desire on the part of the German facilities to have a diversity of supply within their own country, so to speak. Second, some German utilities were the ones that expressed concerns to me with respect to the capability of getting material out of the country, that is, an export license, which in their view is caused by the Nuclear Non-Proliferation Act. So that seems to be why they have terminated contracts.

Mr. Roth. So, in a sense, we are forcing them to go and do it alone, so to speak, or to go out on their own to do some of this work. Is that correct?

Mr. Voigt. Yes.

Mr. Roth. So, on one hand, we are saying look we want to contain this proliferation as much as possible and on the other hand, our policy is actually causing proliferation.

Mr. Voigt. It has had that trend, yes.

Mr. Roth. I think this question of proliferation is most important. The problems the world is facing today are, in my opinion, like comparing a flea to an elephant with this problem of proliferation because if this thing gets out of hand, there is no saving us. And I see that from the testimony we have had here this morning I think it is fabulous the kind of world we could have. But if we let things like this get out of hand, I am afraid what could happen to us.

Mr. McCormack. Any other questions?

Mr. ROTH. No.

Mr. MCCORMACK. Mrs. Bouquard?

Mrs. BOUQUARD. Thank you very much, Mr. Chairman. I wanted to compliment you gentlemen on your very fine testimony. I know it took a great deal of time to prepare it and also——

VOICE. We can't hear you.

Mrs. BOUQUARD. I want to compliment you gentlemen on your very fine testimony. I know all the work that goes behind the paper that is before us. I was very concerned, and really I have been for some time, about proliferation. I think we are looking at the problem of proliferation entirely wrong. I think if we can provide services to our allies and to developing countries, if we are going to say to them, yes, we do have the ability, we have a reliable technology that is going to contribute to your economic stability and the development of your country, this is going to provide a sense of stability and security to these countries that will greatly override any security that an atomic bomb could ever produce. And I think that we are going to reduce motivation and incentive for proliferation by going the route that you mentioned, by providing these services to our allies. And I was very interested also in the charts and the amount that the Soviet Union is producing for sale. Would you care to comment on that in relation to our program?

Mr. VANSTRUM. I really cannot comment in detail on the Soviet program. They are competing in the world enrichment market and I believe that their pricing is based more on policy considerations than on economics. I guess, having spent my lifetime in the enrichment business, I hate to see somebody compete in that manner when I know we have got the best and lowest cost enrichment capabilities.

Mr. MCCORMACK. Could I follow up on your question?

Mrs. BOUQUARD. Go right ahead.

Mr. MCCORMACK. Mr. Vanstrum, you spoke about providing enrichment services——

Mr. VANSTRUM. Yes, sir.

Mr. MCCORMACK. In recent public addresses I have made, I have talked about the United States providing a nuclear fuel cycle center, speaking of reprocessing, and leasing fuel elements to anybody as long as they had IAEA supervision. It would seem to me that we are really talking about the same thing, whether enrichment or reprocessing and I am curious to know if what you are advocating is that we simply provide service, leasing fuel elements to anybody as long as it has this security in order to dissuade them from attempting to set up their own reprocessing or their own enrichment facilities.

Mr. VANSTRUM. I think the same underyling idea is there. In my paper, I indicated that in the case of uranium enrichment, it might be advantageous to work cooperatively with some country that is rich in uranium who might want to do enriching. Also, I think your idea is a good one that we might be able to get involved in the action through collective enterprises and further the same kind of endeavor in the uranium enrichment business, or possibly for the entire fuel cycle, that you suggested for reprocessing.

Mrs. BOUQUARD. I would like to add that with the proper security constraints. I qualify my remarks. It is my understanding really that a major component of the cost of enrichment is the cost of power. Among these three competing separation technologies, what are the

relative benefits in terms of energy and resource conservation, which is a major factor also?

Dr. MERRIMAN. Our projections at this time of the energy requirements for each of the three AIS processes is that they will be low, in the neighborhood of that of the gas centrifuge, which is a few percent of the gaseous diffusion energy requirement. In the area of resource conservation, one of the things having a low cost enrichment process allows you to do on an economic basis is to extract a greater amount of the uranium 235 from the normal uranium. Our projections are that this might extend the resources by something on the order of 20 percent.

Mrs. BOUQUARD. How would this technology be affected by the decision to work with thorium fuel cycles?

Dr. MERRIMAN. That is an entirely different fuel cycle. The technologies that we have discussed today are being developed for the light water reactor uranium-235 fuel cycle.

Mrs. BOUQUARD. Thank you very much, gentlemen.

Mr. MCCORMACK. Mr. Duncan?

Mr. DUNCAN. Thank you, Mr. Chairman. I asked a question a while ago where, in answering, you described the basis on which the Department of Energy considers it wise, cost effective, to narrow its isotope separation technology down to one by fiscal year 1981. Can you explain the reason for that?

Dr. MERRIMAN. Mr. Duncan, I am not a representative of the Department of Energy, so I can only offer my own observations.

Mr. DUNCAN. We were informed, when I asked the question awhile ago, that you were the one.

Dr. MERRIMAN. I certainly will be pleased to give you my perspective.

Mr. DUNCAN. We would like to have that, yes.

Dr. MERRIMAN. Hoping that it is helpful.

Mr. DUNCAN. Shoot.

Dr. MERRIMAN. I think that in the AIS program, we have the happy dilemma of having three processes with high potential. One of the things that you want to do in that situation is to consider a range of strategies to be certain you're on the right course to realize the greatest overall benefit to the country. In a very practical sense, the issue comes down to allocation of resources. The basic question is how far you should carry multiple approaches along to reduce technical risks, even if this causes delays in deployment, versus concentration of resources on fewer approaches with the objective of earlier deployment, which speeds the benefits. Answering this question is very complex and requires a thorough programmatic risk assessment which would need to include several factors, such as evaluations of the status and potential of each technology, the nature of the problems left to be solved, the resources and time required to solve these problems, the types of alternatives and suboptions each process offers, the potential for technology advances, and possible technical and schedule risks. With this in mind, one obvious option is to set up some kind of select on criteria and choose a winner at the end of the basic science phase. This, of course means that the leader has to wait until the other competitors reach that point. Another alternative, which we certainly think well of, would be to start now and try to go through the whole set of issues I just mentioned, things that address both the technical problems and the programmatic points, and establish readiness criteria

which would represent conditions under which each of the technologies could reasonably be taken to the development module phase. Then, whenever a process meets these criteria, assuming it still shows potential, we could go forward. This would not delay the leader.

Mr. DUNCAN. Do you consider it wise to reduce the technology down to one? Do you think it can be done by 1981? That is a year from now.

Dr. MERRIMAN. Again, I think our observations have been that it might be more prudent in the long run, balancing risks and benefits, to carry two technologies through the development module phase. This would probably not be on a simultaneous schedule and assumes that the leader would not be unduly delayed.

Mr. DUNCAN. One other question. Where would the advanced modules likely be built, here at Oak Ridge?

Dr. MERRIMAN. I might comment on that by pointing out that we have separated uranium isotopes here in Oak Ridge using the thermal diffusion, electromagnetic, gaseous diffusion, gas centrifuge, aerodynamic, and chemical exchange processes. We also have much experience in handling both uranium and UF_6. We are, in addition, supporting the R. & D. efforts on all three of the advanced processes. So I certainly believe that we could accommodate any of the technologies that we have talked about this morning. I believe there is just something about east Tennessee that makes isotopes separate better. [Applause.]

Mr. DUNCAN. Thank you very much. Thank you, Mr. Chairman.

Mr. MCCORMACK. Those were good questions, Mr. Duncan. Mr. Flippo?

Mr. Flippo, you are next.

Mr. FLIPPO. Thank you very much for your testimony. I appreciated that.

I wanted to make sure I did not misunderstand one of the statements that you made. Did I understand you to say, that if non-U.S. countries have the capability to enrich to, I believe you said, 3 percent, that they would have accomplished approximately 60 percent of the work they need, to go to weapons grade enrichment?

Mr. VANSTRUM. That is in terms of the separative work—the difficulty of making the separation. It is a little more complicated than that. I don't want to make it sound too easy to go from 3 percent enriched to weapons level, but in terms of separative work, the 3-percent level represents about 60 percent of the total effort to reach weapons level material.

Mr. FLIPPO. Then if you would, sir, I would like to refer to chart 26 about this proliferation, and again, if you would, help me better understand what you are saying there. You said of the enrichment technology proliferation, at the top, that misconceptions have clouded the proliferation issue—the facts are that:

Any power reactor fuel enrichment process represents a proliferation risk;

That technology does evolve, and so forth, the other points that you make there;

That uranium enrichment technology may pose a proliferation risk comparable to plutonium.

Mr. VANSTRUM. What would you like for me to elaborate on?

Mr. FLIPPO. Well, these factors are not factors that would encourage most people to want to go forward with uranium enrichment, it would seem to me. Is that a reasonable——

Mr. VANSTRUM. The way I look at it is that if we confront the problems for what they really are, we are in a much better position to deal with them. I feel that enrichment technology made freely available throughout the world could represent a proliferation risk comparable to that of plutonium; consequently, we should continue to protect the essential details of the U.S. technologies by the tools noted in my slide—classification, security, safeguards, et cetera. To discourage foreign nations from developing their own enrichment technologies, I feel that we can offer them an alternative—to use the United States as a low-cost, reliable supplier of enrichment services under realistic safeguards. These people who need reactor fuel will get it either by developing their own enrichment process—in which case we will have no influence on how it is used—or by buying it. If they buy from us, we have an opportunity to achieve some of our nonproliferation goals.

In the past, we have all been concerned about proliferation but we have taken actions which in fact have had negative impact on our ability to effect proliferation objectives. The lack of selling enriched uranium, the Nonproliferation Act, which has many of the objectives that we all want of cutting down on proliferation, in fact have had a negative impact on our ability to influence proliferation. The point I am getting at is not that I want to scare people away from enrichment, but rather that I want them to confront the issue and then come up with a policy which minimizes the risk of proliferation and that the best chance, as I see it, to reduce the risk of proliferation is to proceed with an aggressive U.S. policy on enrichment, in an active way to be a part of any action rather than be off on the side observing others going into the business. That is the point I want to make. I think you can only come to proper conclusions if you recognize the problems for what they really are.

Mr. FLIPPO. How do you reply to those who say we don't want them to develop their technology? Many countries have that technology now for uranium enrichment and are competing for the world market and it appears to me that current American policy or part of the DOE program and your programs are designed to produce to serve non-U.S. markets, outside this country. How would the programs be affected, how do you react to the people who say don't let them have the technology, we will sell them the material from which they can take and enrich further if they have that capability, to weapons grade? If I understand your arguments, you are saying that we need to proceed with uranium enrichment to meet United States and international market demand.

Mr. VANSTRUM. I certainly feel that we should proceed with uranium enrichment to meet United States and international market demands, under appropriate safeguards, rather than force other countries to develop their own enriching capabilities over which we would then have no influence or control. I think the point is that nuclear power is an active and viable industry that will go ahead regardless of what the United States does. As a leader and pioneer in this industry, I am saying that we should maintain a leading role. That's not a bad thing

for the rest of the world; that's a good thing. We can help the rest of the world avail themselves of nuclear power in an efficient, cost-effective way, and I think we should. Others can do it, and others will do it, if we sit on the sidelines. We should stay involved to actively participate and influence the nuclear industry in a positive way. For example, we might be able to exert beneficial influence in promoting effective and acceptable safeguards by approaches such as suggested by Congressman McCormack for international cooperation on a nuclear fuel cycle center which would include enrichment and reprocessing.

Mr. FLIPPO. Thank you very much for your opinion.

Mr. ROTH. Mr. Chairman, I was just going to mention this. I think, Congressman Flippo, that we tried that and that didn't work and it seems to me we have, as an example, the Arab oil where we are trying to become energy self-sufficient. We don't want to be dependent on other nations and I think that is the way the other nations look at us, they don't want to be dependent on us.

Mr. MCCORMACK. Dr. Merriman and Mr. Vanstrum, I want to express my own appreciation and the appreciation of the committee for your excellent testimony today. I have dozens of questions that I wrote as you were making your presentations. I have written all over your testimony, such as here, with questions that I simply don't have time to ask. The time we have allowed ourselves has expired. We would like to go on, but as a matter of fact, we have three meetings in the next hour before we start our lunch. So we simply cannot go on. I think this pretty much describes the choice and frustration of working on this committee. It is a tremendously exciting experience to learn, to visit facilities and sites in Oak Ridge and the laboratories here, to ask questions and to learn from the leading scientists of the world. At the same time, it is frustrating because we don't have enough time to get into it as far as we would like to. And the same thing applies to the time to solve our problems. One of our responsibilities as a committee is to attempt to set the goals and policies for energy development of the Nation, and many times we can see broad outlines quite clearly that we would follow and details within those outlines quite clearly in many cases, and find ourselves frustrated by confusion and a lack of definition of programs in our Congress and the Government in general. But we obviously are quite interested in moving forward and taking advantage of the information and knowledge and wisdom that you can share with us and we very much appreciate our visit here today, this hearing and the contributions all of you have made and I know we will look forward to coming back and visiting you again.

I want to thank Congresswoman Bouquard for hosting us here today, she is a wonderful teammate for all of us.

Mrs. BOUQUARD. My thanks, Mr. Chairman and the committee and members of the staff for being with us today.

Mr. MCCORMACK. I want to thank Congressman Duncan for joining us and for asking such good questions.

We stand adjourned. Thank you.

[Whereupon, the hearing was concluded at approximately 11:35 a.m., on Saturday, September 22, 1979.]

APPENDIX

Additional Material Submitted for the Record

EXXON NUCLEAR COMPANY, Inc.

777 - 106th Avenue N.E., C-00777, Bellevue, Washington 98009, Telephone (206) 453-4300

L. R. RAYMOND

September 21, 1979

The Honorable Mike McCormack
Chairman, Subcommittee on Energy
Research and Production
U.S. House of Representatives
B-374 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. McCormack:

We thank you for the opportunity to participate in the important hearings on advanced enrichment technologies which your subcommittee will be holding in Oak Ridge on Saturday, September 22. Although I will not be able to attend personally, we are pleased to submit a written statement for the record which I hope will be helpful in your deliberations.

To summarize our principal views, we consider it extremely important that DOE get on promptly with the task of installing the initial 2.2 million SWU/year increment of the Portsmouth GCEP, as currently authorized, and preparation to install additional increments as and when necessary; and further, that some concrete steps be taken to encourage prompt development and demonstration of other even more advanced enrichment technologies, particularly including the highly promising laser enrichment technique. Because of its bright prospects for tails-stripping and more energy-efficient, less capital-intensive operation, the latter technology has the potential for complementing the existing DOE gaseous diffusion and planned gas centrifuge enrichment complex and, meanwhile, conserving valuable resources by effectively stretching the nation's uranium resources by about 20%. Successful development of LIS and centrifuge enrichment capability would also permit the gradual retirement of the much less energy-efficient diffusion plants, should that become necessary or desirable at some future time.

In view of your prior personal interest in the matter I might note that, as explained in the enclosed statement, we do not plan to formally protest DOE's decision to exclude Exxon Nuclear from the Portsmouth GCEP centrifuge machine procurement program. Accordingly, we have initiated steps toward closing out our existing centrifuge manufacturing and testing operations in Malta, N.Y. and Richland, Wash. Also, of course, we are abandoning plans to construct new manufacturing facilities in Oak Ridge.

Sincerely yours,

L. R. Raymond

Enclosure

STATEMENT FOR THE HEARING RECORD

SUBMITTED BY EXXON NUCLEAR COMPANY, INC.

Introduction

Exxon Nuclear Company, Inc. has been actively involved in the uranium enrichment phase of the nuclear fuel cycle virtually since the Company's inception a decade ago. We have supported, and continue to support, the construction of additional domestic uranium enrichment capacity to meet both domestic and foreign needs. This support is based upon the need to assure ample and economic supplies of enriched uranium for domestic and overseas power plants; the need for the U.S. to retain its technological leadership in this vital sector; and the need to restore this country's faltering "reliable supplier" image. In furtherance of these objectives, we believe the U.S. Government should (1) move forward vigorously with timely construction of the initial increment of the Portsmouth Gas Centrifuge Enrichment Project (GCEP); (2) prepare to install later planned increments as and when needed; and (3) encourage the prompt development and demonstration of the even more advanced enrichment technologies, particularly including this nation's leading and highly promising laser isotope separation (LIS) technique. Without such encouragement, we doubt that LIS developmental work will emerge from the research phase in a timely fashion--if at all--domestically. Furthermore, we believe that proper governmental encouragement and assurances are needed now if Government policymakers have any real hope of eventually transferring responsibility for future enrichment capacity expansion into the hands of qualified private enterprise.

Background Information

In addressing the matter of uranium enrichment, Exxon Nuclear does so from a background of substantial corporate interest and commitment--not only in the enrichment sector, but throughout the entire nuclear fuel cycle.

Exxon Nuclear is a supplier of fabricated fuel and uranium for nuclear electric power plants in the U.S., Western Europe and the Far East. In addition, Exxon Nuclear has conducted extensive research and development in other nuclear fuel cycle sectors, including laser enrichment, centrifuge enrichment and spent fuel reprocessing. The Company, which employs more than 1,250 persons, is headquartered in Bellevue, Wash., with nuclear fuel manufacturing, research and technology, laser enrichment development and centrifuge test facilities in Richland, Wash. Additional centrifuge manufacturing facilities are located in Malta, N.Y., with associated offices in Oak Ridge, Tenn. The Company has its European Office in Brussels, Belgium, with nuclear fuel assembly and manufacturing facilities in Lingen, West Germany. An Exxon Nuclear subsidiary employs an additional 950 persons at the Idaho National Engineering Laboratory, and about 900 employees of affiliated companies are engaged in uranium exploration and production activities in the United States and abroad.

At the invitation of DOE's predecessor agency, Exxon Nuclear has been an active participant in DOE's Industrial Participation (IP) Program for uranium enrichment since our original selection by the AEC in 1972. The announced purpose of the non-government funded IP Program has been to encourage industrial participation on a privately-financed basis in the uranium enrichment sector. Exxon Nuclear has invested over $40 million in centrifuge development, engineering and testing, an amount believed to be the largest private investment by any single company in the field. We were among the first industrial companies to be certified by DOE as a qualified centrifuge manufacturer, and have supplied a substantial number of centrifuges for use in DOE facilities. In addition, as discussed in more detail hereinafter, Exxon Nuclear has invested more than $60 million through a subsidiary company in development of a proprietary laser enrichment technique independent of the IP and other government programs.

Reasons For Expanding U.S. Uranium Enrichment Capacity

There are a number of reasons which point to the need for a more aggressive program to expand U.S. enrichment capacity.

- First, the U.S. is rapidly losing its position as a major supplier of enriched uranium to the Free World. As U.S. uranium enrichment policies have vacillated, DOE has been losing overseas customers because of their perception of the U.S. as an unreliable supplier of enrichment services. It is now estimated that the once paramount U.S. share of the total foreign (Free World) enrichment market will shrink to about 35-40% as early as 1985, and will continue its downward trend thereafter unless prompt corrective action is taken.

The U.S. has stated repeatedly that it will take all necessary steps to assure other nations the U.S. will be a reliable fuel supplier to those who adhere to effective non-proliferation policies. Adequate enrichment capacity is, of course, a cardinal aspect of supply reliability--as expressly acknowledged in the Nuclear Non-Proliferation Act of 1978. However, the halting progress on the Portsmouth GCEP hardly seems likely to instill genuine confidence in our trading partners that the U.S. is seriously preparing to follow through on its global commitments in this regard.

Anything short of an aggressive program to reestablish the U.S. as a reliable supplier of uranium enrichment services will be inimical to this nation's non-proliferation goals and may ultimately lead to technological dependence on other nations. Moreover, declining nuclear exports affect domestic employment, the nation's balance of payments, and its technological leadership in the international community.

- Second, while the present gaseous diffusion enrichment complex may, under <u>some</u> supply/demand scenarios, appear to be sufficient to meet the needs of DOE's domestic and non-U.S. customers for the near and intermediate term, we believe that such optimistic projections are based more upon physical capacity calculations than prudent assessments of actual production capability. Overly conservative demand estimates provide no room for an aggressive program to expand nuclear capacity in this country, an option which should remain open as a response to the continuing reliance on imported fuels for the generation of electricity. The supply projections, for the most part, ignore the potential

for massive shortfalls in domestic enriched uranium production which may be occasioned if DOE continues its policy of reducing its consumption of electrical energy in the gaseous diffusion complex when other requirements or considerations arise. They also fail to give adequate consideration to the potential inability of DOE's electrical energy suppliers to complete generating projects on schedule thereby denying DOE the additional increments of firm power necessary to meet enrichment capability projections.

o Third, we believe that the post-TMI assessment and present lull in nuclear plant orders will eventually culminate in a call for expanded development of nuclear power to help meet the energy needs of the U.S. Our nation cannot afford to allow pessimistic predictions of reduced demand for uranium enrichment services brought about by the current debate to lead us into a misguided and unalterable reduction in our plans to increase enrichment capacity. Shortsightedness at this time could foreclose future energy options which, in later retrospect, may well be found essential not only to our own national energy security needs but to our friends and allies as well, whose more aggressive nuclear energy programs are continuing. Even if, contrary to expectation, it eventually develops that additional capacity is not needed as early as projected--or, indeed, even in the highly unlikely event that substantial additional capacity is not needed at all--the present energy-inefficient gaseous diffusion complex could gradually be retired and replaced by advanced technologies if, as expected, they prove to be more economically attractive and energy efficient.

o Fourth, it is essential that we press rapidly forward with development of advanced enrichment technologies. These more energy-efficient technologies cannot be truly proven unless production size plants are constructed and operated. Once such plants are proven to be commercially feasible, availability of the new technology would allow better planning for future enrichment needs. For example, it might be possible to replace, in whole or in part, the high energy consuming gaseous diffusion complex with more energy efficient technologies, thereby freeing up for other pressing needs a corresponding share of the 7,000 megawatts of electric power which will be required to operate the diffusion plants at full capacity. The more efficient new enrichment technologies would also further enhance the economic and conservatory benefits of nuclear power by improving the nuclear fuel cycle to yield greater energy benefits in return for energy investments, to the direct benefit of all electric power consumers. Further, implacement of these advanced enriching technologies could be the key to reestablishment of the United States as the dominant force in international nuclear fuel supply, with the attendant benefits of increased influence on non-proliferation matters and favorable impact on our balance of payments.

To summarize, we believe that construction of additional uranium enrichment capacity using more energy-efficient advanced concepts is absolutely necessary in order to regain U.S. technical superiority in the vital uranium enrichment sector, to reduce the use of energy by the uranium enrichment plants, to retain current and hopefully gain new overseas enrichment service customers, and to guard against a possible shortfall in enrichment production brought about by future electricity shortages. In view of these overriding considerations, short term budgetary considerations should not be permitted to delay the construction of facilities using an advanced technology which clearly is ready for commercialization. The government planning process too often reacts to short term

needs without considering the long term problems which must be addressed, particularly in an industry which vitally needs long term assurances in the form of supply security.

The Senate, in the most recent version of the DOE FY'80 authorization, has expressed its interest in receiving, by February 1980, a comprehensive DOE expression of enrichment policy prior to consideration of the FY'81 budget. A similar House request would put the Congress on record in support of advance and prudent planning. If a true long-term enrichment policy and plan were in place, adjustments on a year-by-year basis could be more rationally evaluated.

Need to Encourage Private Industrial Participation and Investment

Early in his Administration, President Carter decided that the Government itself should undertake installation of the next unit of needed enrichment capacity expansion, by constructing the Portsmouth GCEP as an "add on" to the existing DOE enrichment complex. In view of this decision, we believe the Government should get on with the task, certainly as to the first 2.2 million SWU/year increment of GCEP capacity. However, the Government policymakers must consider the somewhat longer term question of how follow-on enrichment capacity expansion will be installed. Earlier, DOE decided on a construction and operational plan for the GCEP which, in our view, is considerably less than optimum from the originally announced standpoint of fostering an orderly expansion by private industry into this enterprise. Recognizing the industrial realities, we believe that encouragement to private industry is absolutely necessary now if the Government policymakers have any real hope of eventually transferring to private industry the responsibility for future enrichment capacity expansion.

We are still hopeful that with proper and timely Governmental encouragement and assurances related principally to the political and institutional uncertainties surrounding this industry, private capital can and will be made available for future expansion. Failing that, the only alternative will be for the Government to construct all four planned increments of the GCEP (at an estimated cost of $8 - $10 billion), and for expanded Government investment in the additional enrichment facilities which almost certainly will be needed thereafter. Correspondingly, exclusion of private industry from other sectors of the nuclear fuel cycle will require major Government investments in, among other things, the multiple reprocessing plants which almost surely will be needed in this country at some point, present policy to the contrary notwithstanding. The Federal budgetary implications--not to mention the social and political implications--of such massive governmental involvement and expenditures in areas well suited to private enterprise are enormous. Practically speaking, it seems quite likely that any such Federal expenditure profile would come into increasing budgetary conflict with social welfare and other more traditional government programs, and suffer in the competition.

DOE Centrifuge Procurement Program

As you know, Exxon Nuclear was not among the three industrial firms recently selected by DOE for contract negotiations to supply gas centrifuge machines for the Portsmouth GCEP. We were extremely surprised and disappointed by DOE's

decision. We believe Exxon Nuclear had the most highly respected team of technical experts in DOE's industrial participation program. However, DOE apparently did not agree, although to this point the precise reasons for our non-selection have not been made entirely clear to us in meetings with DOE which we have found less than wholly satisfying. Regrettably, DOE has refused to release its Source Evaluation Board and associated reports to us so that we could more fully understand the actual reasons for our elimination and assess its possibly broader implications. We are continuing to seek the DOE evaluation reports to which we have been initially denied access.

We have received a number of inquiries--including helpful congressional inquiries and expressions of support--as to our future plans in this regard. However tempting, we do not plan to formally protest our non-selection. To do so would be a useless exercise, we believe, since even a successful appeal would likely be a hollow victory. Moreover, we are not anxious to afford any basis for interrupting the present GCEP Project schedule, through purported legal impediments or otherwise. Accordingly, Exxon Nuclear has initiated the process of disposing of its centrifuge manufacturing facilities and equipment, terminating contracts and subcontracts, and relocating affected employees.

Potential Benefits of Laser Isotope Separation

In addition to the substantial commitments to centrifuge enrichment, Exxon Nuclear has invested over $60 million in the field of laser isotope separation (LIS). This investment has been made through a subsidiary company ("JNAI") jointly owned by the Avco Everett Research Laboratory. JNAI has been engaged in pioneering the development of this proprietary atomic vapor LIS technique since early in 1971, when we originally established the scientific proof-of-principle of the concept. JNAI holds a substantial patent position in the LIS technology.

The JNAI concept lends itself to the enrichment of natural uranium (as is accomplished by existing and planned enrichment facilities) and also to enrichment of depleted uranium tails (that is, the waste stream rejected by existing facilities). The development and implementation of the technology could provide the alternative of using laser enrichment facilities to replace existing less efficient plants or could complement them by "mining" the tails stockpile and converting its contents to low enriched fuel suitable for conventional nuclear power plants. LIS technology cannot realistically and should not be considered as a substitute for the timely increments of the Portsmouth GCEP in view of the laser process demonstration work yet required. Rather, demonstration and implementation of the laser technology would complement the present enrichment capacity expansion plans by serving as a backup for the earlier GCEP increments or, possibly, by displacing one or more of the later increments, depending on the ultimate GCEP deployment schedule; or, further, by replacing portions of the much less energy-efficient diffusion plants. The laser enrichment technique is estimated to have energy requirements comparable to those of the energy-efficient gas centrifuge technology but is expected to offer a significant capital cost advantage relative to centrifuges. In addition, its unique ability to process tails material and thereby extend uranium resources provides an option not economically available with centrifuge or diffusion technology.

The JNAI concept is judged to be highly proliferation-resistant, primarily due to the diverse and highly complex technologies which comprise it. During the fall of 1978, a Blue Ribbon Panel was invited to make an independent assessment of the JNAI laser isotope separation program and to advise on whether continued development of the technology would be consistent with the aims of U.S. nuclear non-proliferation policy. In its unanimous report, the prestigious Panel--comprised of 12 persons with substantial scientific, foreign policy, and arms control expertise--found that continued JNAI development and domestic deployment of its LIS process for the production of low enriched uranium would be consistent with U.S. non-proliferation objectives. The Panel further found that successful development of the process could enhance both the economics and fuel resource base for light water reactors. (See "Laser Isotope Separation: Risks and Benefits," 2-volume report dated February 27, 1979 by the Laser Enrichment Review Panel chaired by Dr. T. Keith Glennan.)

During our nearly nine years of vigorous R&D efforts, process developments have continued with the program emphasis having shifted steadily toward operational testing of full scale equipment, component and system engineering, and plant conceptualization directed toward commercialization. In all, the program has developed to the point of transition between laboratory scale operation to that of integrated demonstration utilizing commercial-scale equipment. Accordingly, as the next step in development, we had originally contemplated initiating prompt construction of an Experimental Test Facility (ETF) at Richland, Washington, the principal objectives of which would be to demonstrate process licensability, perform integrated large-scale testing of all key laser isotope separation steps, and proving operability of crucial items of equipment under commercial-scale conditions. This next step would require a substantial investment--on the order of $150 million, including both capital and associated R&D costs. However, proceeding immediately with this major step would be difficult in view of the current uncertainties, particularly including increased uncertainties as to the eventual opportunity for participation by private industry in the enrichment sector.

The incentives for continuing an aggressive development program which will lead to the deployment of LIS production plants are great. The technology has the potential for processing natural uranium and "stretching" the nation's uranium supplies by over 20% by processing depleted uranium. This would in turn help assure adequate U.S. indigenous uranium reserves; lessen U.S. dependence on foreign energy supplies; help restore U.S. technical leadership in nuclear fuel cycle technology; help reestablish the U.S. as a reliable supplier of enriched uranium; provide increased U.S. leverage in obtaining foreign adherence to effective non-proliferation policies; mitigate the deteriorating U.S. international trade deficit; and help relieve federal budgetary pressures by providing a more cost effective technology option. On the other hand, our confidence in this highly promising technology unfortunately is not matched by equal confidence in other key factors which have a direct bearing on private investment in the field at this time.

In view of the status of and incentives for the development and deployment of the advanced JNAI laser enrichment technology, it is our present intent to seriously examine the alternatives for proceeding with the next major program step within the uncertainties of the enrichment business outlook and opportunity. While doing so, we plan to continue research and development on the process. We intend in the weeks ahead to solicit the views and advice of various appropriate Government officials, including members of this Subcommittee, on various possible alternatives and hope that we may receive your assistance and support.

Thank you for the opportunity to submit this written statement on this most important subject. We hope and trust that your committee will continue to monitor developments in the uranium enrichment area to assure that congressional mandates are indeed met on a timely basis.

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