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URANIUM ENRICHMENT IN THE UNITED STATES

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James H. Hill, Deputy Manager
Joe W. Parks, Chief, Plans & Analysis Branch
Oak Ridge Operations
Energy Research & Development Administration
Oak Ridge, Tennessee

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HISTORY

The construction and capacity expansion of the three U. S. gaseous diffusion plants took place over a twelve year period from late 1943 to late 1955. In the ten years following World War II, military requirements for enriched uranium increased, and during this interval a vigorous gaseous diffusion development effort was maintained so that in the early 1950's, when new enrichment facilities were required, the research and development efforts returned handsome dividends in improved performance. In addition to the U. S. facilities constructed in the early 1940's at Oak Ridge, new cascades were built at Paducah, Kentucky and at Portsmouth, Ohio. These plants were operated at high production rates until about 1964. As requirements for enriched uranium for military purposes declined, separative work production dropped to a low in 1970.

The average annual separative work production levels of the 3-plant complex since 1944 are shown in Figure 1. In anticipation of an increasing demand for enriched uranium to fuel civilian nuclear power plants, contracts with power suppliers were negotiated to begin a program of electrical power restoration to the enrichment plants. Power levels have been almost doubled since the low in 1970. The average power level in 1975 is expected to be about 3700 megawatts with a total separative work output of about 12 million separative work units.

As increasing numbers of civilian nuclear power plants were ordered, programs were initiated that would allow the U. S. enrichment facilities to service more enriching customers. The first program entails the preproduction of enriched uranium fuel. This is possible because the production capability of the enrichment plants will be greater than the annual demands through 1980. Production in excess of needs is being placed in inventory. This inventory will be utilized during the early 1980's at which time the annual demand for enriching services will exceed the production capability.

At full power of 6065 megawatts the current plants have a separative capacity of about 17.2 million separative work units. To increase capacity, two plant improvement programs were initiated, the Cascade Improvement Program and the Cascade Uprating Program. These programs will increase the production capacity from 17.2 million to 27.7 million separative work units per year. These plant improvements are projected to be completed during 1981 at a total cost in excess of one billion dollars.

IMPROVEMENT PROGRAMS

The Cascade Improvement Program will incorporate into the existing diffusion plants the most recent advances in diffusion technology. Increasing the efficiency of the diffusion plants will result in an increase in capacity of about 5.8 million separative work units per year without requiring an increase in electrical power consumption. This is being accomplished by installing improved barrier (the permeable membrane through which the uranium diffuses and U-235 enrichment occurs) and modifying other major components in approximately 90% of the largest stages in the three U. S. plants. New barrier will be installed in about 3000 diffusers, and 3650 compressors will be modified to use more efficiently the existing power. The Cascade Uprating Program will uprate the improved diffusion plants to permit operations at power levels of up to 7380 megawatts which will further increase the capacity by about 4.7 million separative work units per year. This is accomplished by rewinding electrical motors, uprating electrical switchyards and distribution systems, and modifying cooling systems. These modifications involve approximately 4000 stages. Upon completion in 1981 of these two programs, the enriching complex will have been fully improved, and no significant additional gains in separative capacity are expected. While small gains in separative capacity may result from improved technology, we have placed the maximum size equipment into the cell housings and thus have essentially exhausted the flexibility for increasing production capability within the existing plants.

STATUS OF ELECTRICAL POWER AVAILABILITY

To utilize the separative capacity of the unimproved plant, as well as that of the Cascade Improvement Program and the Cascade Uprating Program, electrical power must be available. Electric energy is supplied to the Oak Ridge and Paducah plants by the Tennessee Valley Authority. Electric Energy Incorporated also supplies the Paducah plant, and the Ohio Valley Electric Corporation supplies the Portsmouth plant. The status of contracted electrical power for the 3-plant complex is summarized in Figure 3. The timing of these power increases is illustrated by Figure 4. Some of this power is not firm and a discussion of the uncertainties in its availability is appropriate. Power supplied by the Tennessee Valley Authority (TVA) is tied to their generating capacity. As the generating capacity of the TVA system reaches certain prescribed levels, additional power is contractually made available to the gaseous diffusion plants at Oak Ridge and Paducah. In addition, the last two increments of power to the Oak Ridge and Paducah plants are on a "best efforts" basis until 1984. The electrical power contract with the Tennessee Valley Authority for the last 395 megawatt block of power required to bring the power level to 6065 megawatts was signed in October 1973, and this contract stipulated that power would not be delivered on a firm (one hundred percent availability) basis until ten years after contract execution. Likewise, that power supplied by the Tennessee Valley Authority for the Cascade Uprating Program for Oak Ridge and Paducah, 925 megawatts, will not be delivered on a firm basis until August 1984. As a result of discussions with the Tennessee Valley Authority, we estimate that 50% of the 395 megawatts required to bring the level to 6065 megawatts and 35% of the 925 megawatts Cascade Uprating Program power to be delivered from the Tennessee Valley Authority will be available during the period prior to 1984.

The timing and relative magnitude of the uncertainties as to the availability of restoration and Cascade Uprating Program power is illustrated in Figure 5. The dotted line on Figure 5, "Expected Power", is that schedule which we are using for planning purposes and assumes the 50% availability of restoration power and 35% availability of cascade uprating power. The lower line, "Firm Power", however, is power that the Tennessee Valley Authority is firmly committed to supply. The top line reflects the power schedule if the Tennessee Valley Authority is able to supply the full contract level before it becomes firm in the 1980's. The production of separative work is very dependent on the availability of power as illustrated in Figure 5. For example, if only firm power will be available, 8 million separative work units would not be produced during the years 1978 through 1984, relative to the production from the "Expected Power" levels. However, if all contracted power were delivered during these years, an additional 11 million separative work units would be produced relative to the production from the "Expected Power" levels. Therefore, during this 7 year time period, the gaseous diffusion plant separative work production could vary by as much as 19 million separative work units. Our operating plan is based on the "Expected Power" level.

DEMANDS FOR URANIUM ENRICHMENT

The United States currently has two basic types of uranium enriching services contracts. The first is the requirements-type contract, and as the name implies, this contract stipulates that the U. S. facilities supply enriching services based upon the actual requirements of an individual reactor. For example, if a reactor is delayed or requires less enriched uranium, the requirement for enriching services is also delayed or reduced. The requirements type contract offers the enriching services customer much flexibility as to the extent of his contractual requirements for enriching services. The other type of contract is the long-term, fixed-commitment contract. This contract specifies the amount of enriching services to be provided at given time intervals independent of the operations of a particular reactor. While the enriching customer has less flexibility with the fixed-commitment contract, it provides the U. S. enriching complex a basis for long-term planning. Figure 6 illustrates the status of uranium enrichment contracting activities as of February 20, 1975. The long-term, fixed-commitment contracts are divided into two categories -- those which are firm and those which are conditional. The latter group are conditioned upon the generic statement on the recycle of plutonium as currently being analyzed in the United States by the Nuclear Regulatory Commission (NRC).

As specified by our President's August 6, 1974, statement, all enriching requirements under contract, whether they be firm or conditional, will be guaranteed enriching services through June 1982. After this date, the level of U. S. contractual commitments will be determined by the acceptance or rejection of plutonium recycle. For example, through June 1982, 363,000 megawatts will be supplied enriching services from the U. S. gaseous diffusion plants. If plutonium recycle is accepted by the NRC and private industry installs adequate enriching capacity, the demand upon the U. S. enriching facilities will be reduced to 350,000 megawatts. These conditions would require that the U. S. plants operate at a tails assay of .30%. If plutonium recycle is accepted and no U. S. private enriching facilities become available, the 363,000 megawatt commitment could be supported at a tails assay of .33%. If plutonium recycle is rejected, 290,000 megawatts could be supported at a tails assay of .3 or 320,000 megawatts could be supported at a tails assay of .36 .

OPERATING PLAN FOR THE U. S. ENRICHING FACILITIES

The objective for the operating plan for the U. S. gaseous diffusion plants is to maximize the production of enriched uranium to meet contractual commitments and provide an operating inventory and stockpile to cover contingency situations. There are several variables associated with the operations of a diffusion plant that could affect the operating plan. These variables are depicted in Figure 7.

Two meetings have been held in Oak Ridge, Tennessee, for presentation of the proposed operating plan for the gaseous diffusion plants. The first meeting for U. S. toll enriching customers was held February 13, 1975, and the second meeting for non-U. S. toll enriching customers was held February 28, 1975. These meetings were called to provide industry with more specifics on the operating plan including the choices and tradeoffs which were necessary. The operating plan presented in these meetings was announced January 6, at which time a proposal was made to increase on July 1, 1976, the transaction tails assay from .2% to .275%. For a given quantity and assay of enriched product, the transaction tails assay determines the amount of feed material to be supplied and the amount of separative work for which the toll enriching customer will be billed. The transaction tails assay influences the operating plan to the extent that it controls the amount of normal uranium furnished the enrichment complex and therefore the assay of the operating tails. The maximization of separative work is constrained by the actual delivery of electrical power from our power suppliers as compared with estimated delivery. Power availability as well as the scheduled plant improvements limit the amount of separative work produced by the U. S. diffusion plants. The operating plan is a function of power availability, feed availability, and plant production capacities. These input variables are the determinant of two output variables, operating tails assay and enriched uranium production. Only two sources of natural uranium feed were considered in formulating the operating plan. One source is feed that will be furnished by toll enriching customers to meet their enriching services and the other is a limited stockpile of natural uranium feed owned by the U. S. Government. The purchase of normal uranium feed by the Government was not assumed.

Currently, the U. S. enriching plants transact at a tails assay of .2% and will transact eventually at a tails assay of .3%. The .3% tails assay is essentially fixed by our contracting commitments. Our long-term objective is that the transaction tails and operating tails assay will be the same, thus providing strictly a tolling service and avoiding the sale or purchase of feed. In our planning we assume that about 85% of the U. S. enriching customers and about 40% of the non-U. S. enriching customers will recycle plutonium. These percentages represent the fraction of fixed-commitment contracts that have been submitted with alternative appendices based on plutonium recycle. A determination had to be made of the path to be taken from the current transaction assay of .2% to the ultimate assay of .3%. Following an analysis of the requirements for feed by the diffusion plants to allow higher operating tails and to increase the stockpile of enriched uranium, it was judged that a transaction tails assay of .275% beginning July 1, 1976, would be necessary. Also, a further increase in the transaction tails assay from .275% to .3% on July 1, 1981, was assumed for planning purposes. As illustrated on Figure 8, with the .275% transaction tails assay in effect over the period July 1, 1976, to June 30, 1981, and without purchase of natural uranium feed by the U. S. Government, our planning indicates that the gaseous diffusion plants could be operated at a tails assay of .3% through FY 1976; .28% in FY 1977; .275% in FY 1978 through FY 1979; and .3% for FY 1980 through FY 1982. During the years FY 1983 through FY 1985, the tails assay may be increased to .335%.

In constructing this operating plan, the assumed level of power availability is that power previously presented as the "expected" level. Also, we are planning to supply all firm and conditional contracts for a total of 363,000 megawatts of electrical generating capacity through June 30, 1982. After that date, the last 13,000 megawatts of contracts entered into would be terminated in the event that U. S. private enriching capacity is available.

The lower portion of Figure 8 indicates the separative work stockpile as projected for the time period through FY 1986. At the end of FY 1986, the annual demands for enriching services approximately equals the annual production capability of the U. S. enrichment plants, an inventory of 28 million separative work units is projected. This inventory is intended to offset any potential shortfalls in production capability in addition to providing backup quantities of separative work for new enrichment plants. Any support for delays in plutonium recycle other than as provided under the generic statement provision of the enriching services contract is not part of our planned use of the preproduction stockpile. The preproduction stockpile must first be used to meet our contractual and agreement obligations under Agreements for Cooperation for Peaceful Uses of Atomic Energy. A portion of this inventory is working inventory necessary to operate the gaseous diffusion plants and will not be available as a contingency stockpile. Our current estimate of this working inventory is approximately 7 million separative work units at an ultimate steady-state production rate of 27.7 million separative work units per year. Thus, 21 million separative work units are available to backstop new enriching plants and to protect our contractual obligations against possible contingency situations.

WORKING INVENTORY OF ENRICHED URANIUM

The working inventory of enriched uranium provides for two kinds of needs: (1) material tied up during the time required to physically handle and deliver enriched product to toll enriching customers, and (2) the operating flexibility needed to assure customer's delivery in the month they request as provided in the long-term, fixed-commitment contracts.

An illustration of the volume of product the U. S. enriching plants will be handling gives some indication of the need for this inventory. At full production, we will be supplying needs for almost 400 customers each year, just over one customer per day, each customer averaging perhaps four different assays of enriched uranium. Delivery of product at the full output of the plant, 27.7 million separative work units per year, on the average, will be at a rate of about sixteen 2-1/2 ton cylinders per day.

Preparing product for shipment at the exact assay requested by the toll enriching customer, whether withdrawn from the cascade at the desired assay or prepared by blending from material in inventory, takes considerable time and there must be a sufficient working inventory to meet this need. The activities and estimated timing required to fill a toll enriching order are shown on Figure 9. This figure illustrates the timing required for (a) withdrawing from the cascade, (b) cooling the withdrawal cylinder, (c) inspecting, cleaning, repairing, and filling the customer cylinder, (d) cooling, sampling, and analyzing the customer cylinder, and (e) allowing a margin to adjust the assay. On the average, the total elapsed time from product withdrawal to delivery of enriched uranium to the toll enriching customer is forty days. During this forty day period required for product handling, we will, on the average, withdraw product into about one hundred and fifty 10-ton cylinders and then transfer this product into about six hundred and fifty 2-1/2 ton cylinders for shipment.

While all of the steps are not required for each shipment, they occur frequently enough to require preparation. As a matter of logistics, most of the enriched uranium destined for shipment in a given month must be available for shipment by the first of that month to assure that shipments can be made in the month requested.

The long-term, fixed-commitment contracts assure, within limits, the delivery of enriched uranium according to the customer's requested delivery date. The contract allows us to delay delivery to avoid compaction of orders. Orders for enriching services are far from being a nice, smooth average; our experience has shown wide fluctuations in month-to-month and even quarter-to-quarter deliveries. Analyses indicate that a two-month inventory of product needs to be available to meet peak delivery demands. The 60-day inventory allows greater latitude in providing delivery of product as desired. Hence, in our planning we have provided for two months' inventory to assure the ability to manage the operation of the plants to meet contractual obligations set forth in the fixed-commitment contracts. The requirements contracts, with shorter notice, add to the need for a working inventory.

The two components of the low assay working inventory to provide the cover as previously indicated are shown below:

Working Inventory

Product Handling	40 Days
Contract Flexibility	60 Days
	100 Days

At the fully improved and uprated production levels this hundred-day inventory equates to about 7 million separative work units. It is important to note at this point that we have not operated our enrichment plants at the fully improved and uprated levels, thus we have no basis for determining whether the forty-day and sixty-day inventories are additive or overlap. Our judgment at this time is that there may be some overlap, and with more experience at higher production and demand levels, the size of this inventory may possibly be adjusted. For now, however, we believe a hundred day or 7 million separative work units to be a prudent estimate of the needs for this coverage.

POSSIBLE FACTORS AFFECTING DEVIATIONS IN THE OPERATING PLAN

The operating plan for the U. S. enrichment plants is highly dependent on many variables, several of which are independent of input from the enriching plant operator. All parties involved in the nuclear fuel cycle have a part to play in its long term planning. These parties include the mining and milling industries, fuel fabricators and reprocessors, electric utilities, and the enriching plant operator. Changes in the assumptions and the basic planning input from these groups will result in changes in the operating plan.

The uncertainties in the demand for enriching services may be illustrated by the use of Figure 10. This figure illustrates the three basic types of demands for enriching services. Shown on the lower portion of the figure are the demands for nonpower and other customers. The next increment of enriching services are those covered under fixed-commitment contracts which represent about two thirds of the requirements placed upon the enriching plants. The top portion of the bars are those commitments with requirement-type contracts. Because "nonpower and other" requirements are small, deviations from projections will have little impact on enrichment planning. Fixed commitment contracts, which represent the greatest demand on the U. S. enriching plants, are fixed by contract. Demand for separative work and feed receipts for these contracts are predictable. However, we have offered to modify the fixed-commitment contracts to permit delays in deliveries for enriching services. Such slippages will have the effect of reducing the height of the bars for the years beginning in FY 1976. With lesser demands, slippage will result in additional material going into inventory. This is a positive factor relative to the stockpile previously discussed. A condition for this slippage is that feed schedules are maintained as originally planned and not affect feed availability. Due to the nature of requirement contracts, the requirement for separative work is not a fixed quantity but may vary dependent upon the operating parameters of individual power reactors. These potential variations present us with uncertainties in demand for enriching services and with uncertainties in the feed supply to the U. S. enriching plants which affect the availability of feed for cascade operation.

Since the preparation of the operating plan, substantial slippages in the demand for enriching services for requirement contract holders have been experienced. Also, the U. S. inventory of normal uranium feed is being rapidly depleted. With reduced demands and the associated reduced feed availability from 1976 through 1980 operating tails may be adjusted. We may find, at least temporarily, a reverse split tails situation with operating tails below transaction tails assays. We are presently taking a very close look at the expected feed receipts from requirement contract customers to fine tune our planning during the remainder of this decade. Any reduction in the operating tails assay assumed in the operating plan will result in the production of less enriched product and a reduction in the separative work stockpile. If the growth of nuclear power accelerates, the demand for enriching services may increase and offset any slippages previously experienced.

As previously illustrated, separative work production is highly dependent upon power availability. Factors affecting the separative work production are both on the positive side and the negative side. During the period pre-FY 1986, where power from the Tennessee Valley Authority is delivered on a "best efforts" basis, the separative work production could be increased by as much as 11 million separative work units or decreased by 8 million separative work units dependent upon the ability of the Tennessee Valley Authority to supply power to the Oak Ridge and Paducah enrichment plants. Since the operating plan assumes full utilization of available feed, additional feed is required if the enrichment plant production is increased by the availability of additional power. If additional feed is not available to match the increased power (11 million separative work units), 5 to 6 million separative work units will be added to the enriched uranium inventory. A potential production loss is that less power may be delivered to the enrichment plants as a result of reduced generating capability of the power suppliers. Such was the case when we reduced our power demand from TVA by about 1400 megawatts during November and December of 1974. This reduced power availability resulted in a reduced production during these months of about 700,000 separative work units. The use of brownout conditions during a period of critically short power is a national policy.

The Cascade Improvement Program and the Cascade Uprating Program construction is proceeding essentially on schedule; there is always the possibility that slippage could occur resulting in less than expected separative work production. We have great confidence in our development efforts and are meeting performance goals on schedule and feel that any variance from expected performance gains, if any, will be relatively small. In summary, we are pleased with the progress which has been achieved in these programs and continue to predict that their objectives will be met by 1981 as contemplated. As a measure of progress of the Cascade Improvement Program, 78% of the process hardware is under firm contract.

One factor that may seem extreme is the possibility that a catastrophic type incident such as tornadoes, etc., could lower the output of the U. S. enriching plants significantly. While the probability of these events is low, a switchyard at one of the generating plants supplying power to the Portsmouth diffusion plant was hit by a tornado last year necessitating procurement of supplemental power. Had this additional power not been available, a loss of about 430,000 separative work units would have occurred.

It is evident that the operating plan is dependent upon a number of variables which are not all under our control. These variables affect the demand for enriched uranium as well as the production capability of the U. S. enrichment complex.

Continuing refinement of the operating plan can be expected as changes in these variables occur. The uncertainties mentioned are not unique to the existing U. S. plants but could apply to other plants and plants that will be built in the future.

STATUS OF GASEOUS DIFFUSION TECHNOLOGY

The U. S. Government has supported process improvement work on gaseous diffusion since the inception of large scale uranium enriching plants. In addition to laboratory scale improvement efforts, the process development program also includes the Plant Test Program as a measure of testing and evaluating promising new concepts in full size plant equipment under production conditions. The total support by the U. S. Government for process improvement for the period 1947 through 1974 has been about 225 million dollars for an average of about eight million dollars per year. A cost benefit analysis of the advanced technology already developed under this program shows that the investment has permitted the U. S. Government to save billions of dollars in construction and operating costs of the existing enriching plants. Although these improvements have been extensive and valuable, they do not exhaust the potential of the gaseous diffusion process for further development Since the barrier is the heart of the diffusion process, major improvements have been made in barrier performance since the original plants were built. Modern barrier to be installed in the Cascade Improvement Program has a productivity of about 23 times as high as that installed in the first plants. In the course of our development work, it has been apparent that there remains a potential for further barrier improvements. Such developments will continue in the barrier laboratories and will be translated into full scale barrier production as rapidly as possible to provide an increasing level of barrier quality as the Cascade Improvement Program progresses. These developments will be available for use in new diffusion plants.

By far, the largest block of fuel consumed in the diffusion process is that used to circulate and compress uranium hexafluoride gas at each stage. Developmental work on the process compressors, converters, and interstage ducting has been carried out in the model test and research compressor facilities to produce a package of cost effective improvements which greatly improves the efficiency of the stage gas flow circuit. While these improvements had their origin in models and computer studies, they have been verified in full scale tests in the component test loops.

The improved diffusion technology that will be used in the Cascade Improvement Program has been constrained by the need to work with existing equipment, buildings, and auxiliaries. Through the course of developing advanced technology, it has been apparent that the designer of a new gaseous diffusion plant freed from such constraints could achieve higher equipment and process efficiencies than are possible with existing plants. Conceptual design studies of new diffusion plants and cost estimates have been accordingly a part of the U. S. program to assure that the future separative work needs can be satisfied economically and reliably by U. S. enrichment enterprises. In summary, while the technology developed for the Cascade Improvement Program is applicable to new diffusion plants, there exist other areas including development, engineering and operations analysis studies that have produced much improved compressor designs, staging arrangements, building layouts, drive systems, and waste heat systems which will increase process efficiency and reduce capital investments in new enrichment facilities. Thirty years of large scale operating experience of gaseous diffusion plants along with process improvement efforts have produced a wealth of process experience and technology making this a reliable economical method of producing separative work. The problems of process scaleup were faced in diffusion many years ago and successful solutions developed. Further scaling to achieve an improved economic position in the new plants should hold no surprises.

STATUS OF U. S. GAS CENTRIFUGE ADVANCES

Since 1960, the U. S. Government has carried out an expanded program to develop gas centrifuge processes and to ascertain its economics for enriching uranium on a production scale. Our principle objective is to demonstrate that the centrifuge process is an economic competitor with gaseous diffusion. This demonstration is based on the construction and operation of a pilot plant which will have a capacity greater than that published for the Dutch plant at Almelo, Netherlands. This pilot plant, which is known as the Component Test Facility, will begin operating by January 1976 and will use centrifuges produced at two manufacturing facilities called Component Preparation Laboratories. These laboratories are demonstrating the technology for mass production of the machine components and their assembly.

Reliability testing of a variety of centrifuge designs is a continuing part of the program to prove economic viability of gas centrifugation. The centrifuge development program is continuing to evolve machines of greater economic potential utilizing the new insights on the internal gas dynamics and separation theory of the centrifuge. The U. S. technology now being demonstrated will require numbers of machines in the tens of thousands for a nine million separative work unit plant.

In addition to the current demonstration of centrifuge technology, we have initiated engineering studies on major production plants and their supporting facilities. The U. S. technology already developed for the machines and support systems provides the designers and decision makers a great deal of latitude in the values of the operating parameters which affect the configuration of the plants.

To summarize our efforts on the gas centrifuge process, we are now concentrating our machine developmental efforts on the machines which will be economically competitive with gaseous diffusion. Reliability test of these machines will be initiated in about 18 months. Mass production techniques are being demonstrated and refined in the Component Preparation Laboratories. Start up of the pilot plant will soon begin. Conceptual studies are well underway to further define new enriching facilities.

TRANSFER OF ENRICHMENT TECHNOLOGY

Qualified U. S. companies have access to classified uranium enrichment technology under the Domestic Access Program and the 10 CFR Part 25 Access Permit Program. Under these two Industrial Participation Programs, industrial organizations are afforded continuing access to classified information on gaseous diffusion and/or gas centrifuge technologies. The Domestic Access Program allows firms to perform independent development work on the gas centrifuge and/or gaseous diffusion uranium enriching technology or on the technology of the manufacture of enriching equipment systems. The Access Permit Program allows industry to evaluate the commercial feasibility of constructing and operating a privately owned uranium enrichment facility in the United States and makes Government technology available for use in its design. Current activity in the Industrial Participation Programs continues to be concerned with bringing the Industrial Participants to a high level of confidence in the two technologies. This is being accomplished by making reports available, by allowing the participants to assign their specialists to these government development programs, by scheduling periodic consultation visits, and providing procurement assistance. Briefings and seminars are also incorporated in the program as a mechanism for transferring technology to the participants. During the last two years, over 1300 clearances have been granted and approximately 5700 documents provided to industrial participants. In addition, there have been over 2000 industrial visits and conferences at Government development sites. During this same time interval, private industry has invested several million dollars in their own industrial development, design programs, and facilities.

GASEOUS DIFFUSION-GAS CENTRIFUGE COMPARISON

This discussion is intended to provide further insight into the relative position of the gaseous diffusion and the gas centrifuge uranium enrichment processes as candidates for use in new enrichment plants. The previous section highlighted the scope and character of our efforts and identified the various facilities being used for demonstration of enrichment technologies. Mention was made that a number of centrifuge models are being developed with a promise of achieving competitiveness with gaseous diffusion provided that performance reliability and cost targets are met. The continuing progress in technology and the accumulating process experience clearly supports the view that the centrifuge can be a competitive process for one of the new enrichment plants that will be required to be in production operation in the 1980's. In addition to the relative economics of enrichment by the gaseous diffusion process or the centrifuge process as presented at this conference by William J. Wilcox, Jr., in his paper "Process Selection for New Uranium Enrichment Plants," there are other factors that need to be weighed to determine the relative merits of the two competing processes. Those factors favoring the gaseous diffusion process include the following: gaseous diffusion is a well demonstrated process on the basis of large scale experience over a quarter of a century; technological risks are minimal and capital and operating costs exclusive of power are predictable with considerable accuracy; business risks are minimized; diffusion plants operate at very high plant capacities; and an industrial base already exists upon which a new diffusion project can depend. Because of these factors, there is greater confidence that diffusion plants can actually supply the demand on the required schedule. Factors in favor of the gas centrifuge process include the following: the centrifuge process uses only about a tenth as much power as does the gaseous diffusion process; the amount of reject heat dissipated to the environment is reduced; construction of the centrifuge plant would not likely be paced by the power supply facility; centrifuge plants somewhat smaller than the nominal nine million separative work unit size may be built without substantial economic penalties; and the centrifuge process has more potential for technological growth than diffusion, providing possible greater technical gains to be achieved during further development efforts.

Industry will have to decide whether or not they will provide this new capacity, how much to provide, and when, and to select which enriching technology that it will utilize. The ultimate decision on which process will be chosen will be influenced greatly by the timing of its need and the corporate philosophy of the particular industry entering the enrichment business.

NEW ENRICHMENT CAPACITY

The President of the United States on August 6, 1974, reaffirmed that the U. S. will remain a major supplier of uranium enriching services. He stated that U. S. enrichment capacity must be increased to meet its own growing needs for nuclear power. As a matter of U. S. policy, the President stressed his intention that such new capacity be available to meet the contractual needs of future U. S. and non-U. S. customers.

The policy of the U. S. is that this additional enriching capacity will be provided by industry. In order to enhance the capability of private industry to provide the additional enriching capacity, an Industrial Participation Program was established in 1971 to transfer the classified technology on both centrifuge and diffusion processes as previously mentioned. Since that date about 30 companies have had access to this technology and at the present time about 15 companies are actively participating in this program, some independently and some in consort or joint efforts.

To assist industry further in providing a private competitive centrifuge enriching industry on a timely basis, the concept of demonstration centrifuge enriching facilities (DCEF) was announced in April 1974. Proposals have been solicited for the construction of centrifuge enriching projects sized in the 100,000 to 300,000 separative work units per year range. This approach assumed the development of private supplier-utility customer relationships and a sharing by both parties of the higher specific cost of enriching services. These projects would be privately financed by qualified companies or joint venture organizations which are U. S. owned or controlled, constructed at private sites and subject to licensing. The Government intends, on the basis of competitive proposals, to assist in the establishment of one or more such projects through certain forms of Government assistance.

The date for responses to the request for proposals for the DCEF has been extended from April 1 to September 2, 1975. The objective of the demonstration program is to aid private industry in establishing a competitive uranium enriching industry based on the gas centrifuge process, at the earliest possible date.

On February 7, 1975, Dr. Robert C. Seamans, Jr., Administrator of the Energy Research and Development Administration (ERDA), named a Project Board for Private Uranium Enrichment to evaluate and then provide recommendations concerning the Government's participation in establishment of a uranium enrichment industry in the private sector. As its first responsibility, the Project Board will evaluate the request of Uranium Enrichment Associates for several forms of Government assistance related to use of Government-developed gaseous diffusion technology in the construction of a large uranium enrichment plant near Dothan, Alabama, estimated to cost $2.75 billion. UEA has indicated that Government assistance, such as the supply of certain equipment and assurance of backup enriching services in case of delay, would be required in order for the project to proceed.

In addition to the above, ERDA has been performing conceptual engineering studies for new enriching capacity that can be used by industry in the event they proceed with new enriching construction projects.

U. S. SEPARATIVE WORK PRICING

The pricing of separative work by the U. S. Government has been based upon a philosophy of recovering the Government's cost over a reasonable time period. The current price recovers the Government's cost over the period FY 1971 through FY 1980. The components of the price, shown in Figure 11, are levelized over that time period. The revised base price for enriching services is $44.25. This base price is reduced by $2.15 for fixed commitment contract customers to recognize the accrued interest on the early prepayments. The base price is increased by $3.55 for requirement contract holders to recognize the uncertainties in demand and therefore the risk involved. Both charges are subject to an automatic increase of 2% every six months effective each July 1 and January 1. Advance notices of 180 days for requirement contracts and 60 days for fixed commitment contracts are required for changes in the prices of enriching services. Also Article III of each of the requirement contracts establishes a ceiling charge of $30.00 per separative work unit, subject to escalation on the basis of changes in the costs of labor or electric power. Current staff studies show that an increase in charges is indicated due to recent large increases in the cost of power.

The Government has a policy of full cost recovery for enriching services and any change to this would require a change in legislation preceded by public hearings and review. Considering that enriching services is the only major component of the fuel cycle not in the private sector, a rationale could be made that the elements of charges should be consistent with those in the other components of the fuel cycle. Since enrichment services is an activity that is providing a service to the private sector, and eventually may be in the private sector, the charge should have provisions for cost not normally experienced by a Government operation. This commercial type service could include elements of costs which would place enrichment services on a more appropriate comparison basis with other primary energy sources supplied by the private economy.

INVESTMENT IN NUCLEAR ENERGY

While I have discussed only the enrichment portion of the nuclear fuel cycle, the relative importance of enrichment as compared with the initial capital investments required in the total fuel cycle is illustrated in Figure 12. As a base I have chosen a 9 million separative work unit new enrichment plant and have compared its investment with that of other portions of the fuel cycle. A 9 million separative work unit enrichment plant will support approximately 120,000 megawatts of nuclear electric power generation assuming plutonium recycle. The associated number of uranium mills, fuel fabrication plants and reprocessing plants are shown in the figure with their initial capital investment and lead times required for construction. Although the nuclear option is highly capital intensive, the investment required for enriching represents only about 3% of the total capital investment.

This analysis serves to illustrate that, even though planning for uranium enrichment is receiving much attention from industry and Government, when viewed in perspective, it is a small portion of the total investment required for nuclear electric power generation.

Figure 1
HISTORICAL CASCADE PRODUCTION

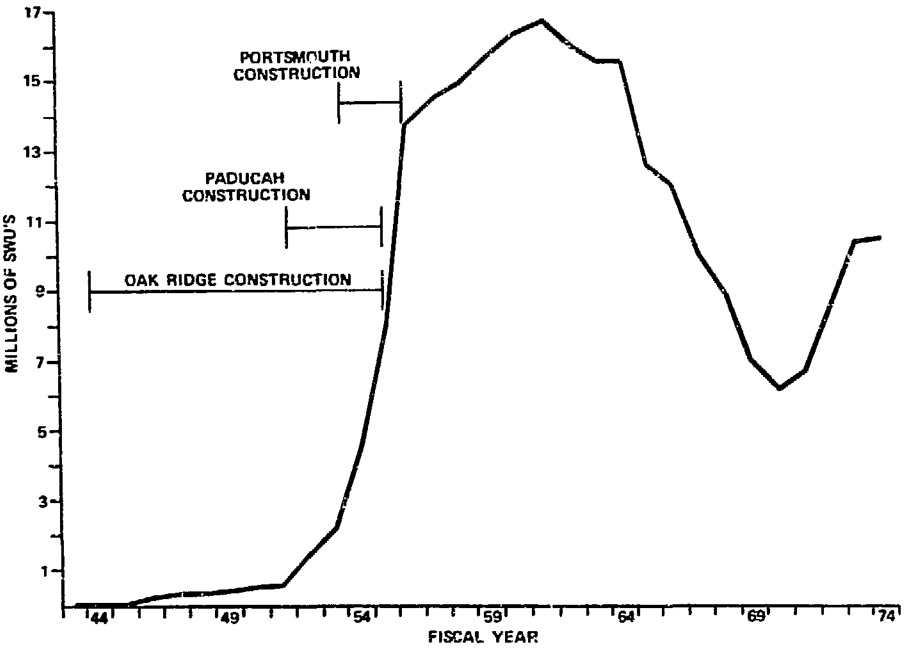


Figure 2
PROJECTED PLANT PRODUCTION

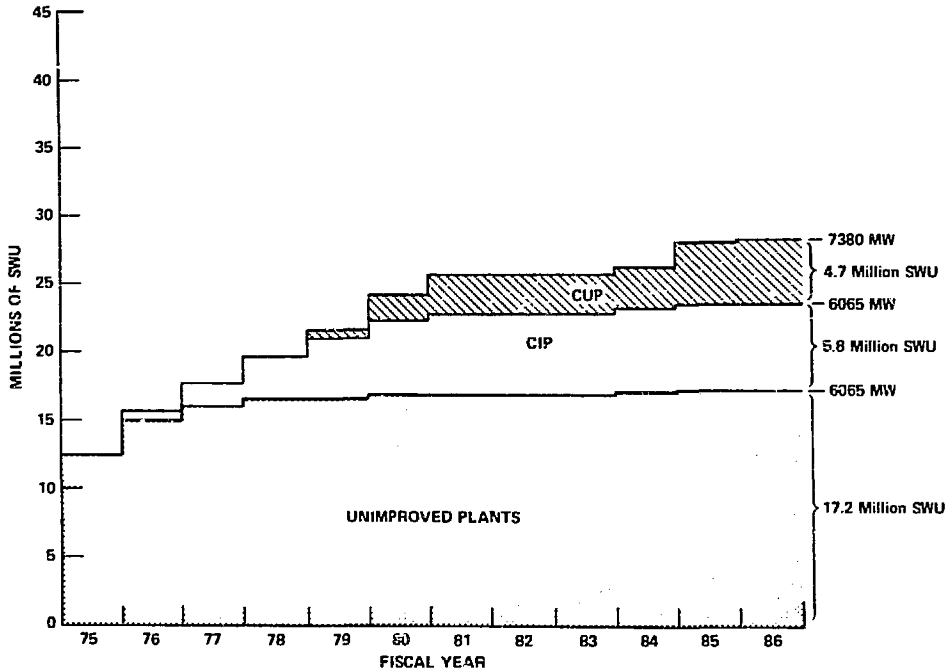


Figure 3

CONTRACTED STATUS (MEGAWATTS)

	OAK RIDGE	PADUCAH	PORTSMOUTH	TOTAL
UNDER CONTRACT				
RESTORATION POWER	1645	2550	1870	6065
CUP POWER	435	490	120	1045
	2080	3040	1990	7110
TO BE CONTRACTED				
CUP	—	—	270	270
	2080	3040	2260	7380

Figure 4

3-SITE GDP POWER REQUIREMENT SCHEDULE

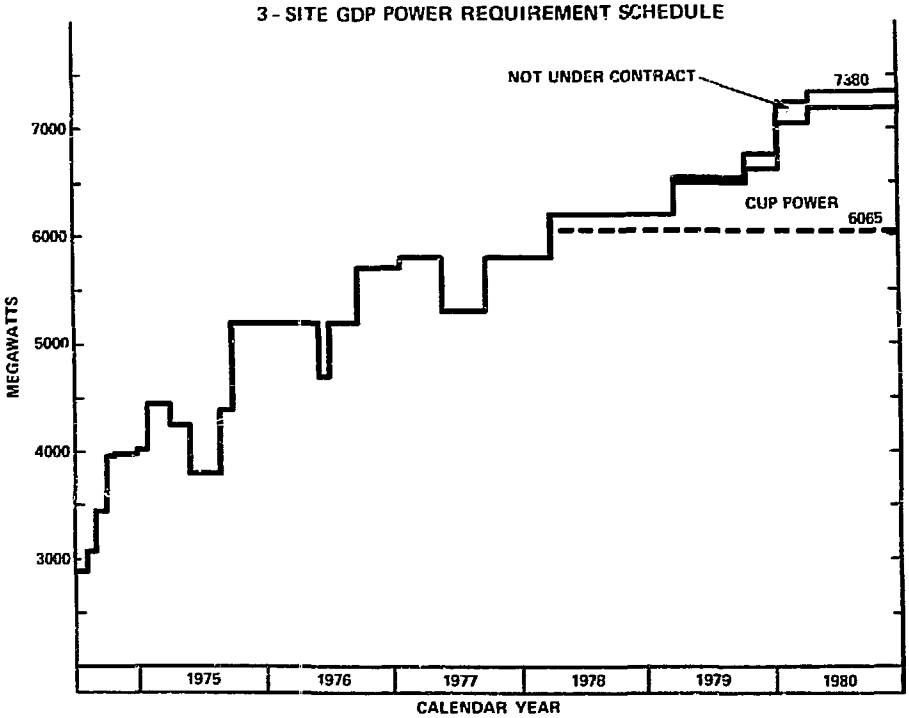


Figure 5

3 - SITE AVERAGE ANNUAL POWER LEVELS

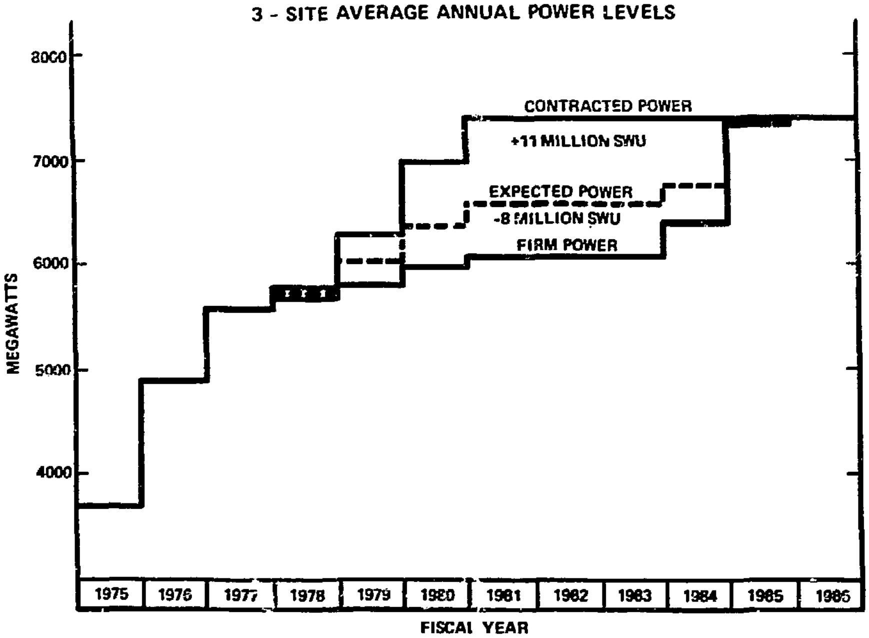


Figure 6

SUMMARY OF CONTRACTS

	NUMBER OF REACTORS	NUMBER OF CONTRACTS	MWE
DOMESTIC			
SIGNED FIXED COMMITMENT	131	131	140,500
TEST REACTORS	1	2	0
REQUIREMENTS	91	53	79,200
	223	186	219,700
FOREIGN			
SIGNED FIXED COMMITMENT	85	85	75,600
REQUIREMENTS	50	47	25,400
	135	132	101,000
SUBTOTAL	358	318	320,700
FOREIGN			
CONDITIONAL CONTRACTS	44	44	42,300
TOTAL	402	362	363,000

Figure 7
DIFFUSION PLANT OPERATING
VARIABLES

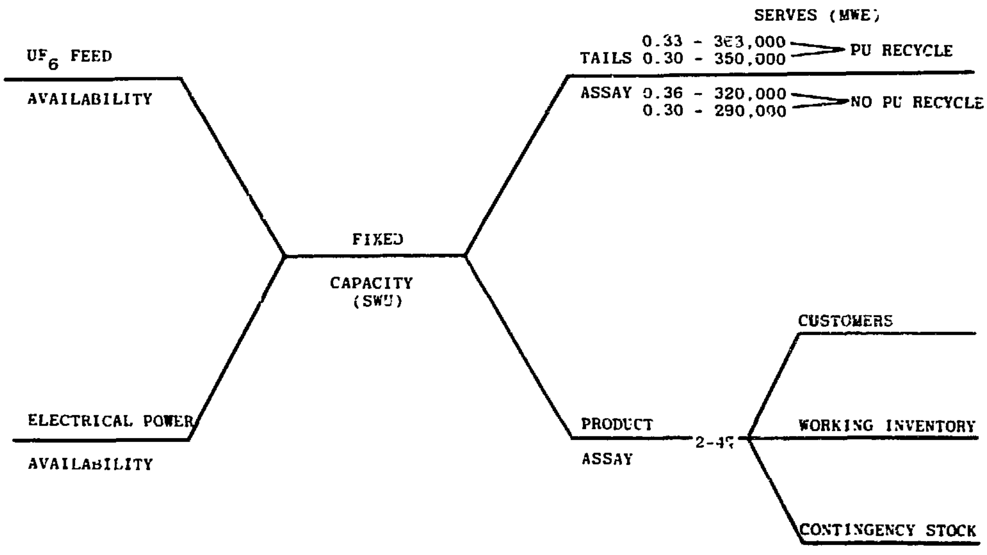
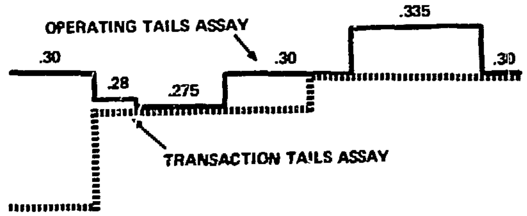


Figure 8

TAILS ASSAY



SEPARATIVE WORK STOCKPILE

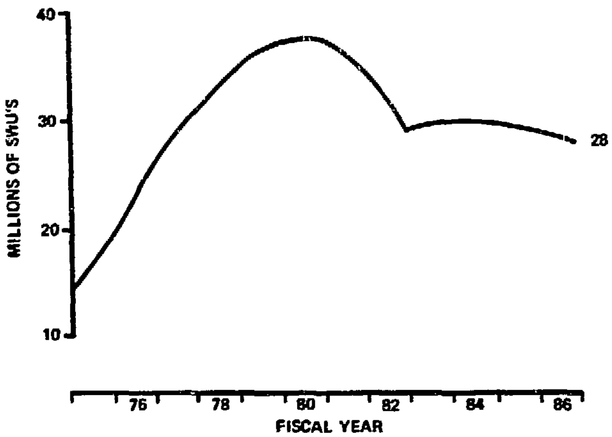


Figure 9
PRODUCT HANDLING TIMING

DAYS	
5	WITHDRAWAL FROM CASCADE
5	COOL WITHDRAWAL CYLINDER
10	INSPECT, CLEAN, REPAIR, AND FILL CUSTOMER CYLINDER
10	COOL, SAMPLE, AND ANALYZE CUSTOMER CYLINDER
10	MARGIN TO ADJUST ASSAY
40	TOTAL

Figure 10

ANNUAL SEPARATIVE WORK PRODUCTION CAPABILITIES
VERSUS
CONTRACTED COMMITMENTS

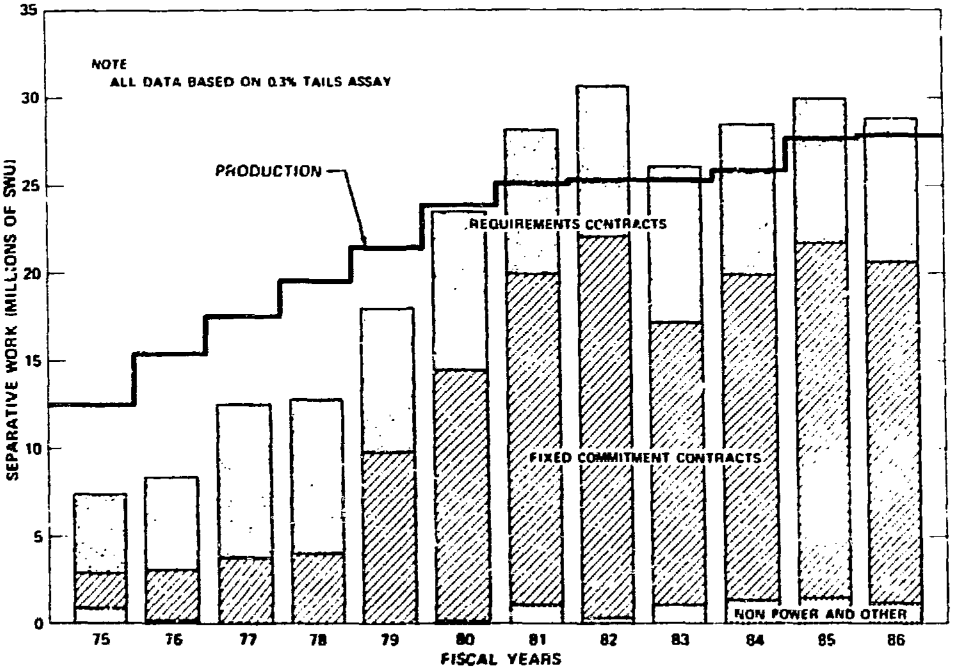


Figure 11

COMPONENTS OF CURRENT ENRICHMENT PRICE

	$/SWU
Power supply	19.25
Other operating costs	3.80
Base plant depreciation, interest and working capital	5.30
CIP/CUP and other plant capital projects	3.75
Interest on preproduction	3.05
Feed supplied by U. S. Government	1.20
Centrifuge r&d	2.15
	38.50
Contingency (15%)	5.75
Current base price	44.25
Less $2.15 accrued interest on fixed commitment contracts	42.10
Plus $3.55 risk assessment for requirements contracts	47.80

Figure 12

FUEL CYCLE CAPACITY TO GO WITH ONE ENRICHMENT PLANT

	Number Of Plants	Initial Capital Investment ($ Million)	Lead Time (Years)
Enrichment Plants (Each 9 Million SWU/YR)	1	1500-2700	8-10
Uranium Mills (Each 1000 Tons U_3O_8/YR)	19	1100-2000	8
Fuel Fabrication Plants (Each 1100 MT/YR)			
Enriched U	2.4	170-210	4-5
PuO_2-UO_2	0.6	70-90	4-5
Reprocessing Plants (Each 1100 MT/YR)	3	1200-1500	8
Nuclear Power Stations	120	60,000-84,000	8-10