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Remarks by
Dr. Glenn T. Seaborg, Chairman
U. S. Atomic Energy Commission
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THE NUCLEAR INDUSTRY--1968 AND BEYOND

It is a pleasure for me to be here and to discuss with this distinguished group the present status and future prospects of the nuclear industry in the United States. This audience represents many of the organizations that will be providing the investment capital for this growing industry; therefore, I think it is important that I and others in the nuclear field take the opportunity to tell you as much as we can about this industry--one that is based on a somewhat complex technology.

I continue to be definitely "bullish" when it comes to nuclear energy. Hopefully the established nuclear industry in serving mankind can also realize a good return on its investment. As regards the future, some of you may have heard or seen my comments during this past year on the potential for nuclear energy centers for industrial and agro-industrial complexes--the so-called "NUPLEX"--that could someday offer dramatic benefits to mankind based on low-cost energy. What I have attempted to illustrate in emphasizing the possibilities of this concept is that low-cost energy is one of our most important assets whether it be produced by fossil or nuclear means. We are fortunate in this country that the utilities have a choice of power systems and fuels, and this stimulates competition and helps us further to achieve our goal of truly low-cost energy.

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Today I should like to discuss with you the recent and prospective growth of nuclear power in the United States, the outlook for associated industries, and the latest developments in the PLOWSHARE program to develop peaceful uses for nuclear explosions.

It has been over ten years since nuclear power was first used in this country to supply electricity to the public on a regular basis. At the time this first plant was being built there were many reputable scientists and engineers who were skeptical about the successful economic use of nuclear energy in central station power plants. Many of these scientists and engineers saw the economic use of nuclear energy as being several decades away. Even the more optimistic of us did not predict what was actually to happen.

Fortunately, I am happy to say, most of us proved to be poor economic forecasters. The cost of electricity from large water cooled nuclear power plants being constructed now is expected to be competitive with that from fossil fuel plants in wide areas of the country. That cost is on the order of five mills per kilowatt hour. Today there is little doubt that the utility industry in the U. S. has accepted nuclear power as a safe, reliable, and the most economic means of meeting a large proportion of its new requirement.

As you may recall, by the end of 1962 private industry and the electric utilities working closely with the AEC had placed in operation around the country several relatively small light water reactors to demonstrate the reliability of nuclear power to generate electricity. But as reliable as these reactors proved to be they were not economically competitive with conventional power plants, and therefore utilities were in no hurry to contract for nuclear plants on their own. A turning point began, however, late in 1963 with the announcement by the Jersey Central Power and Light Company that it had contracted for a 515,000 kilowatt nuclear plant at Oyster Creek near Toms River, N. J., which, according to the company's own economic evaluation, would be competitive with a fossil fueled plant. Jersey Central Power and Light disclosed that its decision had been based upon a company evaluation showing that electricity from its proposed plant would cost about four mills per kilowatt hour, based on the price of the plant tendered by the General Electric Company. This was the first case where a utility had selected a nuclear power plant on purely economic grounds, without Government assistance, in direct competition with a fossil fueled plant.

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Some of you may know of the difficulties that have occurred during the construction of the Oyster Creek plant. The industry has, in effect, cut its teeth with this plant and the growing pains that are evident there have been beneficial in emphasizing the importance of careful supervision, rigid inspection and quality assurance. I commend those associated with that plant for their patience and perseverance in attempting to assure that this plant will operate effectively and safely.

Within the past four years the growth of nuclear power has been nothing short of remarkable. During this time it was realized that the key to the economic success for nuclear plants was their size. Units ranging from 500,000 up to and exceeding 1,000,000 kilowatts could compete with fossil fueled plants in some areas, and would later compete successfully even in areas where these fossil fuels were naturally abundant. A classic example was the decision by TVA in 1966 to build two 1,064 MWe nuclear power plants at the Browns Ferry, Alabama, station. The bus bar power cost for these plants was estimated to be 0.46 mills per kilowatt hour less expensive than the competitive coal-fired plant.

TVA's decision during 1967 to construct an additional 1,065 MWe (1,065,000 KWe) nuclear power unit and the choice of a 1,300 MWe coal-fired power unit, both to be placed in service in 1972, reflected the finding that the relative cost of nuclear and coal-fired units was approximately a standoff at that time on the TVA system. During 1968 TVA evaluated bids for both coal-fired units and nuclear units. The quotations indicated increased costs in both types of plants, and it appeared that coal would be the winner. However, during the process of negotiation it turned out that a nuclear plant was more attractive and TVA ordered two nuclear plants from Westinghouse for operation in 1973 and 1974. The three previous nuclear plants were ordered from General Electric for operation in 1970, 1971 and 1972.

Another important event that occurred just before the surge in orders for nuclear power plants was the passage of a revision to the Atomic Energy Act to permit the private ownership of special nuclear materials (uranium and plutonium) effective August 1964. Prior to this time, all enriched uranium and plutonium had to be owned by the Government and could only be leased to private enterprise. Without this legislation, the Government's investment in uranium for industrial nuclear power production would have been very large indeed and the Government would have had to buy all of the plutonium generated in these nuclear power plants at a "fair value" established by the Government. With passage of this legislation, the Commission was permitted to sell special nuclear materials, and after December 31, 1970, the AEC will no longer distribute such material on lease for commercial power production. All material on lease must be converted to private ownership by July 1, 1973.

One of the most significant provisions of the new policy under this legislation is that beginning January 1, 1969, the nuclear industry can purchase uranium from a private source and have it enriched in the Government's gaseous diffusion plants by paying toll charges. This legislation opened the way for private enterprise to participate more fully in the nuclear power business. At the present time, the AEC will not provide enrichment services for foreign uranium intended for use in domestic reactors but it will provide such services for uranium of foreign origin for use in foreign reactors.

The only step in the nuclear fuel cycle that is not in the hands of private industry now is the operation of gaseous diffusion enriching plants now done entirely by the Government.

With this general over-view of the growth of the nuclear power industry, let me now provide you with some specific numbers and projections that I am sure will be of interest to you.

In talking about the growth of power, we must first talk about the growth of population. In the first figure, showing pictorially past and projected growth in population in the U. S., you will note that the population almost doubles over about a 40-year period. The projected use of electric power in the U. S. considerably exceeds the rate of growth of population--doubling about every ten years. The difference in the rate of increase of population and electrical power is reflected to some extent, as indicated in figure 2, in the increase in per capita consumption of energy.

The forecast of electric generating capacity is shown in figure 3, which indicates that by about 1980 the total will be in excess of 600,000,000 kilowatts. Figure 4 shows the various sources of energy for the production of this electrical power. Nuclear generating capacity by 1980, according to the AEC estimate, will be in the range of 120,000,000 to 170,000,000 kilowatts electrical, or about 25% of the total. You will notice that we certainly do not expect nuclear power to replace coal or other sources on this time scale, but to play an important role in supplementing these sources. The amount of electric energy to be generated in 1980 will be about the same from coal and nuclear sources, since we expect that the nuclear plants will be used as baseload plants.

The curves in figure 5 illustrate the difficulty in making projections more than ten years into the future and that we have a rather conservative batting average in making these estimates; that, in fact, we have consistently been on the low side.

When we issued our 1962 Report to the President we were estimating only 40,000,000 KWe nuclear installed capacity by 1980. We have continued to increase that estimate, and last year we changed it to a range of 120,000,000 KWe to 170,000,000 KWe with a median estimate of 150,000,000 KWe by 1980. I hasten to point out that some estimates have been made by the industry, electric utilities, and manufacturers that are even higher. An estimate contained in the Fast Breeder Reactor Report published by the Edison Electric Institute in April indicates a total installed nuclear capacity in the range of 160,000,000, KWe to 195,000,000 Kwe by 1980 and 1,000,000,000 KWe by the year 2000. During the past year, however, we have reevaluated the basis for our estimates and have decided not to change our estimate of a median of around 150,000,000 KWe for planning purposes, and this is reflected in the charts that follow.

One of the reasons we have had some difficulty in making these estimates is found in the cyclical trend in utility ordering of electric generating equipment. This trend is depicted in the bar graph in figure 6 which shows that one could have expected a possible decline in 1966 or 1967. However, the orders in 1967 were even higher than in 1966.

Perhaps one of the reasons we didn't have the expected decline is that the utilities wanted to get their orders in while they could because of the long lead time required for nuclear plants, and before the manufacturing capacity was saturated. The manufacturers are proceeding with considerable expansion of production capability for nuclear reactor cores, turbo-generators and other components. I understand another reason for the acceleration in orders was that the utilities considered they were getting some good bargains in these plants.

Last year at a Nuclear Forum for Financial Managers I stated that it would not be surprising if the rate of orders for nuclear plants decreased in 1968. At the present time the orders are about 30% less this year than this time last year. The total orders for electric generating capacity based on all sources of power also appear to be substantially less than last year. I think this is a trend that may continue into next year, which seems to be logical considering that the combined electric generating capacity of nuclear and conventional plant orders has doubled about every two years during the past five years while the historic increase for installed generating capacity has corresponded to a doubling time of ten years.

This rush to nuclear power on the part of our Nation's utilities is in part reflected in the plant prices. These prices have varied during this time period from an early low of about $90 per installed KWe capacity to recent highs of about $200/KWe. The average capital cost of plants ordered from 1965 through 1968 is about $150/KWe. Some reactor manufacturers now state that their estimate of capital plant costs is about $170/KWe. However, larger size plants of 1200 to 1300 MWe, which are now being offered for sale, may show lower capital costs of plants. For comparison's sake, the National Coal Association reports that capital costs for fossil plants currently are around $140/KWe. One, of course, must use caution in making any conclusions about variances in capital plant costs because of the differences in accounting practices followed by the various electric utilities.

It appears clear from the cyclical nature of utility plant orders that the nuclear power plant market is in a downswing which may in part be attributable to these increased costs quoted for these reactor units, but is primarily attributable to sales coming back into line with requirements. Hopefully as we get into a buyer's market there will be some reduction in the capital costs of plants quoted. Additionally, if the cyclical nature could be smoothed out to a more uniform order rate, it is conceivable that price increases and delays resulting from saturation of manufacturers' plant capacity might be avoided.

We are all proud of the progress made through the years in broadening the base of the industry and in achieving competition. However, in Washington we do follow the industry very closely to evaluate the necessity for any action by the Government to assure a competitive market. Recently, Arthur D. Little, Inc., completed its study of competition in the nuclear industry for the AEC and the Department of Justice. The nuclear power industry for the purposes of this study consists of firms engaged in the business of supplying reactors, reactor components, nuclear fuel, or other products and services associated with the design, construction and operation of nuclear electric plants, including their entire fuel cycle. We hope that this study will assist the Commission in the preparation of any necessary guidelines for the healthy competitive development of the emerging nuclear industry.

Originally there were two major reactor manufacturers; but during 1966 the reactor manufacturing business spread to other companies, as indicated in figure 7. Eighty-four nuclear power units have been sold to date by these five companies, totaling 61,000 MWe (that is, 61,000,000 KWe). In addition to these nuclear power units that have been sold, utilities have announced plans for an additional 11 units totaling approximately 10,000 MWe, for which contracts have not been awarded. We also understand there are around 15 large units under consideration which may be announced within the next year. We are pleased that there are already five reactor supplier companies participating, which should help to assure that these reactor plants can be manufactured on a timely basis to meet the utilities' schedule. In figure 7 I have shown Gulf General Atomic with two plants. While they are not participating in the manufacture of light water reactors, they have developed a high temperature gas-cooled reactor which began full power operation in June 1967 on the Philadelphia Electric Power system at Peach Bottom, Pennsylvania. They are now constructing a 330 MWe high temperature gas-cooled unit for the Public Service Company of Colorado.

In figure 8, I have shown a tabulation of the growth of nuclear power which includes the growth of U. S. type reactors that will be installed for operation abroad. You will note that the total projected growth of nuclear power for U. S. type reactors by 1980 is approximately 230,000 MWe, of which around 150,000 MWe will be installed in the U. S. This total projection includes U. S. type reactors abroad because we have assured our customers abroad that we will have the capability of providing sufficient capacity to enrich the uranium required for their reactors.

In getting to numbers that we can all understand, we have made projections of the general magnitude of sales for capital equipment and the various steps in the fuel cycle. These estimates are based on what we understand to be an estimated average present price. We have not attempted to make an estimate of the future trend in prices because of the many variables involved in changing technology, increasing economies of scale, and the development of a highly competitive market. I have depicted in figure 9 the annual investment in the construction of nuclear power plants in the United States. Assuming $150 per kilowatt installed capacity, the total investment through 1980 will be approximately $25 billion. The rate of annual investment at that date would be nearly $4 billion.

Figure 10 shows the annual uranium requirements for reactors that will be installed in the U. S. This requirement is shown both in terms of thousands of tons of U_3O_8 and millions of dollars, based on $8 per pound of U_3O_8. This is the price for the natural uranium component (the other component is the cost of enrichment) in the present AEC price schedule for enriched uranium. It may not be assumed to be representative of the prices that the uranium mining industry is getting today or may get in the future. That will have to be established in the marketplace. You will note estimated annual sales of uranium for 1980 of almost $600 million and accumulated sales of about $4 billion. This estimate assumes the reductions in uranium requirements that can be made if the plutonium that has been generated in these nuclear power plants is recycled back to the reactors as fuel beginning in the mid-1970's.

The rapid increase in the projected requirements for uranium has caused some concern within the Commission and in industry as to whether a sufficient amount of material can be obtained to meet these requirements. The known reserves of U_3O_8 in the U. S. capable of being produced at $8 per pound were estimated as of January 1, 1968, at about 148,000 tons. Even though approximately 11,000 tons of U_3O_8 were produced in 1967 the net increase in reserves of ore (U_3O_8) in the ground was 7,000 tons. If we consider reserves available at up to $10 a pound, this estimate can be increased

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to about 200,000 tons. The amount of U_3O_8 required to fuel the projected nuclear reactor capacity through calendar year 1980 is estimated to be approximately 250,000 tons.

This large anticipated demand for uranium has caused a rapid expansion of private drilling activity. At the present time 47 companies are planning a total of 100,000,000 feet of exploration and development drilling, expected to cost approximately $135 million during the four-year period 1968 through 1971. The amount of drilling that is planned has almost doubled from the estimates that were made during 1967. This activity is a principal indicator of the extent of the industry's efforts to expand the uranium reserves.

The success in defining uranium reserves through past exploration is shown in figure 11. Within the next year or so considerably more information, available as a result of the recent greatly accelerated exploratory efforts, should permit us to better assess the future prospects for the development of additional sources of uranium.

Most of the uranium required through 1971 has been ordered, and considerable quantities have been ordered to meet requirements beyond that, in some cases through 1975. Figure 12 shows the material presently on order and the present estimate of material required through 1975. Some of the milling companies have no sales agreements for uranium for commercial purposes extending beyond 1969, and some of the reactor manufacturers and electric utilities have bought more uranium than they will need in the earlier years. One solution to this mismatch of delivery versus requirement of possible benefit to purchasers of uranium would be through the use of a uranium bank, so to speak, in which an owner of uranium can, in effect, deposit his material in the bank to accumulate interest while it is on loan to others. He may withdraw this uranium later on when he needs it. One company has already been established to perform this type of service. This could be a valuable service to the electrical utilities, the reactor manufacturers, and ultimately the customers of electrical power by reducing the burden of carrying charges on a large inventory of very expensive material.

Another choice available is lease of the fuel to the utility by a third party (i.e., a banking institution). The AEC, of course, established the precedent for leasing material since the Government had to own all fissionable material until the passage of the private ownership act in 1964. From this experience the utilities have learned of the advantages of leasing rather than purchasing in certain instances.

The AEC's current lease charge is at the rate of 5-1/2% applied to a price for enriched uranium-235 based on a separative work charge $26 per Kg of separative work currently in effect, and a charge of $8 per pound for U_3O_8 as the natural uranium component. Some banking institutions indicate that they may even be able to compete with this leasing arrangement if they can purchase natural uranium at around $7 per pound of U_3O_8.

In the legislation giving the AEC authority to provide toll enriching services, one restriction imposed was that uranium of foreign origin and intended for use in a domestic power reactor may not be accepted by AEC as feed for toll enrichment until such time as the Commission determines that the restriction can be removed without compromising the viability of the domestic uranium industry. The Commission is pleased with the response of the uranium mining industry in accelerating its exploration program; however, we recognize that we must follow the success of this program very carefully and continue to evaluate the consequences of modifying the restrictions on the use of uranium from foreign sources.

On September 6, 1968, we issued a revised statement on policies relating to uranium supply through June 30, 1973. The AEC will sell uranium on a single transaction basis at a price based on $8 per pound U_3O_8 in concentrates in the event that uranium is not available from industrial sources on the schedule required or is only available at a price exceeding that in use as a basis for the AEC charge. We of course continue to prefer that the natural uranium be purchased from private sources and converted to uranium hexafluoride in industrial plants before being tolled through the Government's diffusion plants for enrichment. The AEC also prefers to sell natural uranium instead of enriched uranium if circumstances permit. In addition, we indicated that we will continue to review the effect of the restriction on imports and will propose its removal at the earliest date consistent with reasonable assurance of the viability of the domestic uranium industry. Presently, it appears that this may be possible by July 1, 1973, or earlier.

After the U_3O_8, or "yellow cake", as it is called, is produced by the milling companies, it has to be converted to

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UF_6. In the form of this gaseous compound--called "feed material"--it is processed through the Government's gaseous diffusion plants for enrichment in the fissionable isotope uranium-235. The magnitude of this work of conversion to UF_6 is estimated in figure 13. The total business through 1980 at present prices of approximately $1 per pound of converted uranium is estimated at approximately $650 million at a rate exceeding $100 million per year at that time. The only industrial capability in existence for the conversion to UF_6 is the Allied Chemical Plant at Metropolis, Illinois. They have announced plans for expanding their annual capacity to 10,000 tons of contained uranium by 1970. In addition, Kerr-McGee has announced plans to build a conversion facility with an initial capacity of 5,000 tons of uranium per year to be operational in 1970. Other companies have indicated an interest in going into this phase of the fuel cycle.

The Government diffusion plants are located at Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky. Improvements in these plants have considerably increased their capacity in the past and can provide substantial additional increases in the future. The annual requirements for separative work are shown in figure 14. This includes the requirements for enriched uranium to be used in U. S. type reactors abroad as well as for reactors to be installed in this country. I have again shown the requirements assuming that plutonium will be recycled beginning in the mid-1970's. Separative work is the highest component cost in the fuel cycle, and with the current price of $26 per Kg separative work the total separative work business is projected to be over a billion dollars per year by 1980, with accumulated sales of over $6 billion by that date.

There has been some concern whether present enrichment capacity is adequate to meet demands for enriched uranium fuel. Currently planned operating schedules and the incorporation of presently planned improvements to the existing gaseous diffusion plants will assure meeting the estimated separative work requirements for domestic and foreign power reactors through about 1980. The exact timing for additional capacity or facilities is dependent upon many factors; for example, the extent of plutonium recycle. As additional enriching facilities are required for the post-1980 period, arrangements for their construction can be made sufficiently in advance to assure they will be available when needed.

The AEC currently is studying the desirability of private ownership and operation of some or all of its enrichment facilities. The enrichment process is the only phase of the nuclear fuel cycle still exclusively in Government hands. One of the stated attractive features in considering operation of enrichment facilities by private enterprise is the stimulation of competition in this major phase of the fuel cycle to possibly further reduce prices and to provide financial capability for the timely addition of productive capacity as it is needed.

I am sure that many of you have seen the Atomic Industrial Forum study published in June concerning the possible transfer of the gaseous diffusion plants to industry. The Forum's study concluded that private ownership of the three existing gaseous diffusion plants is both feasible and desirable and the Government should commit itself soon to an orderly transfer of the enrichment business to private hands. They expressed the view that the best way to accomplish the transfer would be to sell all three plants simultaneously with minimal conditions and restrictions to three separate private organizations.

Another suggested course for transferring these diffusion plants to the private sector is to establish a single privately owned but Government-regulated organization to operate all three existing plants. The ownership of this corporation would be open to both public and private utilities, the major customers of the plants' product, enriched uranium.

Still another manner of operation of these plants that has been proposed is the establishment of an interim Government-owned corporation with the flexibility of issuing bonds to finance future expansion and plant improvement. These three approaches are being considered very carefully along with possible transition arrangements to a complete transfer to industry.

There are, of course, many complex issues to be considered by the Government in examining the transfer of the gaseous diffusion plants. We wish to achieve ideally both competition and maximum efficiency. Any system followed must be capable of undertaking an expensive Cascade Improvement Program almost immediately. Further, the system must be able to meet our domestic and foreign commitments on reasonable terms, within price limits, and to maintain the confidence of these customers. And of course all of this must be consistent with the concept of the non-proliferation of nuclear weapons.

After the uranium is enriched in the Government diffusion plant, it is shipped to a reactor core manufacturer for fabrication into the finished nuclear fuel. The magnitude of business in this increment of the fuel cycle is shown in figure 15. The accumulated business through 1980 is estimated at nearly $4 billion and annual sales are estimated at more than $600 million by that time. This is based on an estimate of a present fabrication price of $90 per Kg of uranium in the fuel. We can expect that, through processing improvement and through the effect of economy of scale with increased production, the cost of fuel fabrication may be reduced by about 5% per year over the next few years. However, the anticipated escalation in the cost of materials and labor probably will offset some of these reductions in price.

You will note that by 1980 the annual replacement fuel sales will be about twice that of the initial fuel. A recent survey indicates that the electric utilities have already ordered or have options for over 50% of the replacement fuel fabrication work that will be needed through 1980.

In all cases the nuclear power plant manufacturer has sold and will manufacture the initial nuclear fuel core for his plant. During 1966, Commonwealth Edison awarded a contract to United Nuclear for a replacement core for the 200 MWe Dresden I plant and this core was installed this year. This was the first time that a major replacement core job has been awarded to a company other than the nuclear power plant manufacturer. Last year the American Electric Power Company awarded United Nuclear the job for replacement cores II and III for AEP's first nuclear plant; this replacement order was placed at the time the plant was ordered from Westinghouse. This year Consolidated Edison awarded replacement core jobs to United Nuclear for Consolidated Edison's fourth nuclear power plant. The initial core will be purchased from General Electric Company, the reactor manufacturer.

Other companies are now engaged or planning to be engaged in various segments of the nuclear fuel cycle for industrial nuclear power plants. Atlantic-Richfield through its recently acquired subsidiary NUMEC, Kerr-McGee, Nuclear Fuel Services, Atomics International, Aerojet General and National Lead have fuel fabrication capabilities in varying degrees. I understand that the Gulf Oil Company is studying the possibility of entering all phases of the fuel cycle from mining to chemical reprocessing and Standard Oil of New Jersey has been making extensive studies on how they might participate most effectively in the nuclear business.

The reactor cores normally operate from one to two years before they are refueled. Approximately 1/4 to 1/3 of the fuel is replaced each year thereafter. When this fuel is removed from the reactor power plant, it is shipped to a chemical reprocessing plant where the residual uranium and the plutonium that has been generated are recovered for further use. The magnitude of the business in chemical reprocessing is shown in figure 16. This is around $500 million through 1980 at a rate of about $100 million per year at that date, at the current price of $32 per Kg of reprocessed uranium. At the present time there is only one chemical reprocessing plant being operated by industry. This is the Nuclear Fuel Services one-ton-uranium-per-day plant at West Valley, New York--a facility owned jointly by the W. R. Grace and Getty and Skelly Oil companies.

It appears that a requirement for additional chemical reprocessing plant capacity will not be reached until around 1972-1973. Between that time and 1980, capacity exceeding present capability by a factor of 10 will be needed. The General Electric Company is building a chemical reprocessing plant in Illinois, Allied Chemical and Atlantic-Richfield have announced plans for building reprocessing plants in South Carolina, and the National Lead Company has been studying the possibility of also building an irradiated fuels reprocessing plant. (The Duke Power Company has reported that it already has contracts with Atlantic-Richfield for reprocessing nuclear fuel.) Other companies have indicated an interest in entering this phase of the business. I feel compelled to caution the industry that, if all these companies build chemical reprocessing plants on the schedule and of the capacity that they have indicated, we will have twice as much capacity in 1975 as will be required for the year 1980. This may be one way of achieving reduced prices for reprocessing but it would not be a very healthy situation in the long term.

The estimate of the total accumulated business in the major segments of the fuel cycle as shown in figure 17 is about $15 billion by 1980, and the annual rate at that time will be around $2.5 billion. Combining this with the projected investment in the construction of nuclear power plants (figure 18) it shows that the utilities total accumulated cost of nuclear business that I have previously discussed will be over $40 billion by 1980, and at a rate of almost $6.5 billion annually by that date.

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For the period beyond 1980, we are concerned about a more efficient use of uranium to conserve our resources and to permit us to use higher cost ore economically. Therefore, we are assigning the highest priority to the development of advanced converter and breeder reactors to accomplish this. We expect that within the next several years we will have sufficient technology to permit the design and construction of a demonstration liquid metal cooled fast breeder reactor, at power ratings of about 200-500 MWe, which could lead to the commercial operation of such breeder reactors in the 1,000 MWe range in the early 1980's.

As insurance against possible delays in availability of economically competitive fast breeders and against failure of a timely increase in our low-cost uranium reserves, we are developing advanced converters such as the High Temperature Gas-Cooled Reactor and thermal breeders such as the Molten Salt Reactor. Both these reactor types work on the thorium cycle and may be economically competitive, even with efficient fast breeder reactors.

If breeders could come into commercial operation with a fuel doubling time of around seven years, then the nuclear power generating systems could become self-sustaining in about thirty years and fuel new reactors as needed. Such breeders when completely developed would use much less uranium ore than present-day reactors, but the uncertainties of development and anticipated continuing role of present-type reactors suggest a good market for uranium through the year 2000 and beyond.

Another area of the nuclear industry I find particularly interesting is the field of radioisotopes, including nuclear gauges and radiation processing. Viewed in broad perspective, it is estimated that radioisotopes are currently generating commercial activity at a level of several hundred million dollars annually in the United States.

Private enterprise is involved in all the major aspects of radioisotope distribution, including private production of radioisotopes and commercial sale of radiochemicals, radiopharmaceuticals, radiation sources, and nuclear gauges. Also, private industry is engaged in the manufacture and sale of radiation-processed materials and radioisotope-powered electric generators. It is also conducting a great amount of research and development in these areas.

Domestic private sales in 1968 of radioisotopes and radiochemicals have been estimated at $10-$13 million and radiopharmaceuticals at $12-$15 million for a total of $22-$28 million. The market increased about 25% over 1967 and the industry is expected to grow at about this rate for several years.

The domestic private sales just cited include the value of AEC supplied radioisotopes purchased for further processing and distribution. AEC's sales of isotopes to commercial users amounted to $1.8 million in FY 1967 and to about the same in FY 1968.

It may be helpful to clarify for you the four classes of radioisotopes of commercial interest: Those found in nature (i.e. radium-226); those produced in nuclear reactors by neutron irradiation (i.e. cobalt-60 and carbon-14); those produced in accelerators (i.e. sodium-22 and iodine-123); and those resulting as by-products from the fission process (i.e. strontium-90 and cesium-137).

One of AEC's responsibilities is to assure that adequate supplies of radioisotopes are available for government purposes and for users in the fields of science, medicine, agriculture and industry. For many years AEC facilities, principally Oak Ridge National Laboratory, filled this demand. Since about 1961, private industry in the United States has developed the capacity to produce and market a great number of the commonly used radioisotopes. The AEC in 1965 adopted formal policies for the transfer of activities related to radioisotopes to private industry. Since 1961 AEC has withdrawn from routine production of 38 reactor-produced isotopes. The last such isotope, cobalt-60, was withdrawn in March 1968 because this isotope is commercially available from General Electric, Neutron Products, Inc., and several foreign sources.

The AEC still produces some 80 radioisotopes not yet available commercially and has just announced the availability of limited quantities of californium-252, americium-243, and curium-244 for use in private research and development. I would particularly like to emphasize the potential of californium-252 as a portable neutron source for use in medical therapy, neutron activation analysis, neutron radiography and hydrology.

Some indication of the volume of business of different segments of the radioisotope industry is given in the following:

Radioisotopes are used for various applications including sources for nuclear gauges, instrument calibration, industrial radiography, and medical teletherapy and as the luminescent materials for instrument panels and signs. This business is currently estimated to be between $2.5-3 million annually and is estimated to be increasing about 20% per year.

Radioisotope gauges are manufactured by some 20-30 firms with a current annual volume of about $25 million. This business is growing at a rate of between 10 to 15% per year.

Radiation processing has reached the status of very large business in the United States. The current dollar volume of sales of products made through radiation processing is estimated by AEC at around $100 million and at nearly $250 million by at least one industry representative. This industry is expected to grow at a rate of about 25% per year.

Let me shift now to a different application of nuclear energy--the AEC's Plowshare program. A number of significant steps have been taken in our Plowshare program since I last discussed this program with the financial community here in New York. As you will recall, Plowshare is the AEC's program for investigating peaceful uses for nuclear explosions in science and industry.

On December 10, 1967, the first joint industry-government nuclear explosion experiment, Project Gasbuggy, was conducted in a low-producing gas field located near Farmington, New Mexico. Figure 19 shows the emplacement of the Gasbuggy explosive. The 26 kiloton nuclear detonation, which was jointly sponsored by the El Paso Natural Gas Company, the Department of the Interior and the Atomic Energy Commission, created a "chimney" 335 feet high with a fracture radius of approximately 400 feet. Evaluations of the data obtained from Gasbuggy to date are very promising. Radioactivity levels were considerably below expectations and the gas flow tests conducted are encouraging. Other gas stimulation experiments, such as Projects Dragon Trail and Rulison, are in the offing to further test out this application.

In addition, we recently negotiated a contract with CER-Geonuclear Corporation, representing some 15 oil and related companies, and the Department of the Interior to jointly investigate the use of nuclear explosives to facilitate the recovery of oil from oil shale. The contract is now being reviewed by the participants in the planned experiment. The

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experiment, dubbed Project Bronco, will consist of essentially three parts. Part one, the nuclear detonation, is tentatively scheduled for the fall of 1969. Subsequent to the detonation an attempt will be made to free the oil trapped in the broken shale in the chimney by the application of heat. Part three will attempt to recover the oil from the shale surrounding the chimney. A site in the Piceance Basin of Colorado has been selected for this experiment.

Another experiment under consideration is Project Sloop which involves the use of underground nuclear explosions to facilitate the economic recovery of copper from low-grade ore.

Considerable progress has been made also in developing the excavation technology for large-scale earth-moving projects such as harbors and canals. On March 12, 1968, Project Buggy, the first nuclear row-charge experiment, was conducted, creating a ditch 65 feet deep, 250 feet wide and 850 feet long, as pictured in figure 20. The success of Buggy is particularly significant because of the critical relationship between a simple effective ditching technique and the capability of using nuclear excavation for the construction of canals or the cutting of mountain passes for roadbeds or railways.

While I would like to conclude my talk today on a completely optimistic note there is one aspect of nuclear energy that I must touch on to be realistic about its future development. In spite of the bright outlook for developing the peaceful applications of nuclear energy we cannot overlook their relationship to the military applications of the atom. This is particularly true regarding two aspects of nuclear energy I discussed today. One concerns the fact that nuclear power plants, while generating electricity, produce plutonium. And plutonium is a basic ingredient of a nuclear weapon. Therefore, based on the projected growth of nuclear power here and abroad, we could be producing by 1980 sufficient plutonium to make potentially dozens of nuclear weapons per day. This is indeed a sobering thought and one alone that should emphasize the importance of the nuclear non-proliferation treaty and the application of international safeguards through the International Atomic Energy Agency (IAEA). Both this treaty and this organization require our strongest support.

I should also point out that nuclear explosives developed for peaceful purposes can also be misused for military purposes, and, consequently, the widespread development of explosives for peaceful purposes could, in effect, result in

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the proliferation of nuclear weapons. A solution to this problem would be to have those nations which have already developed such nuclear devices provide to the non-nuclear weapon nations a nuclear explosion service for peaceful purposes through an appropriate international organization, on a non-discriminatory basis and at a price which would not include the cost of research and development. Happily, I can report that this solution has been incorporated in Article V of the non-proliferation treaty.

In recognition of the increased pace at which Plowshare technology is being developed and in order to underscore our commitment under the non-proliferation treaty, legislation was introduced during the last session of Congress to permit the Atomic Energy Commission to provide a nuclear explosion service on a commercial basis. Previously our authority had been limited to those projects of research and development nature.

I have tried to summarize for you today some of the progress that we have made recently in the nuclear field and indicate the direction in which we seem to be going. The picture is promising. The potential is enormous. However, I would caution you to delve into the background of new companies that may come on the scene and not to assume that, if the company includes in its name the words uranium, atomic, or nuclear, it provides an opportunity to "get rich quick." I am sure that in the days and years ahead prudent investing in our nuclear future will prove profitable not only to the financial community but to men and women everywhere who will gain by our fullest development and use of the peaceful atom.

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