SIDEBAR 1:

Economic Perspective for Uranium Enrichment

The future demand for enriched uranium to fuel nuclear power plants is uncertain, Estimates of this demand depend on assumptions concerning projections of total electric power demand, financial considerations, and government policies. The U.S. Department of Energy recently estimated that between now and the end of this century the generation of nuclear power, and hence the need for enriched uranium, will increase by a factor of 2 to 3 both here and abroad. Sale of enriched uranium to satisfy this increased demand can represent an important source of revenue for the United States, Through fiscal year 1980 our cumulative revenues from such sales amounted to over 7 billion dollars, and until recently foreign sales accounted for a major portion of this revenue. The sole source of enriched uranium until 1974, the United States now supplies only about 30 per cent of foreign demand, New enrichment capacity planned in this country should include means of reducing enrichment costs to permit capturing a larger share of the foreign trade in this commodity. Laser isotope separation shows promise of accomplishing this goal.

Currently, gaseous diffusion is the process by which uranium is enriched at the large-scale production facilities in the United States. Three such facilities exist (at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio) whose total enrichment capacity will soon reach 27.3 million separative work units per year.

Separative work units (abbreviated SWU) are the customary measure of the effort required to produce, from a feed material with a fried concentration of the desired isotope, a specified amount of product enriched to a specified concentration and tails, or wastes, depleted to a specified concentration. For example, from feed material with a uranium-235 concentration of 0.7 per cent (the naturally occurring concentration), production of a kilogram of uranium enriched to about 3 per cent (the concentration suitable for light-water reactor fuel) with tails depleted to 0.2 per cent requires about 4.3 SWU.

Gaseous diffusion is based on the greater rate of diffusion through a porous barrier of the lighter component of a compressed gaseous mixture. For uranium enrichment the gaseous mixture consists of uranium hexafluoride molecules containing uranium-235 ($^{235}UF_6$) or uranium-238 ($^{238}UF_6$). The enrichment attainable per diffusion unit is quite low, being limited theoretically to less than the square root of the $^{238}UF_6$ to $^{235}UF_6$ mass ratio, or about 1.004. Therefore, the slightly enriched product from one diffusion unit, consisting of a compressor and a diffusion chamber, is passed through a second unit whose product in turn is passed through a third unit, and so on. (The theory of separative work and optimal arrangement of separation units was pioneered by R. E. Peierls and P. A. M. Dirac.) To enrich uranium from 0.7 per cent uranium-235 to about 3 per cent requires approximately 1250 units, Gaseous diffusion plants are therefore very large and expensive.

They have, however, proved very reliable. The main disadvantage of the process is the great amount of electric power required to operate the many compressors. A standard gaseous diffusion plant operating at full capacity demands about 3000 megawatts electric. For comparison, a typical large electric power plant produces 1000 megawatts electric. As the cost of electric power increases, its consumption becomes an increasingly important factor in the cost of enriched uranium. (In fiscal year 1980 about 75 per cent of the production costs at gaseous diffusion plants was for electricity.)

With the expectation of reducing power consumption, attention is now focused on the gas centrifuge, another method for enriching uranium. The Gas Centrifuge Enrichment Plant now being constructed at Portsmouth, Ohio will contribute 8.75 million SWU per year to the national enrichment capacity by 1994. In a gas centrifuge $^{235}UF_6$ and $^{238}UF_6$ are separated by the centrifugal force imposed on UF_6 by a rapidly rotating container. For this process a considerably smaller number of centrifuge units (less than 10) are required to reach the desired enrichment. However, the throughput per centrifuge unit is very small compared to that of a diffusion unit-so small, in fact, that it is not compensated by the higher enrichment per unit. To produce the same amount of reactor-grade fuel requires a considerably larger number (approximately 50,000 to 500,000] of centrifuge units than diffusion units. This disadvantage, however, is outweighed by the considerably lower (by a factor of 20) energy consumption per SWU for the gas centrifuge.

Compared to diffusion and the centrifuge, laser isotope separation offers the potential for much greater enrichment and throughput per separation unit. Therefore, a laser isotope separation facility would be much smaller, including only about ten separation units. In addition, the process would consume an equal or lesser amount of energy per SWU than the gas centrifuge. These advantages lead directly to reduced capital and operating costs.

For a laser isotope separation process involving selective excitation of $^{235}UF_6$ molecules with infrared lasers and their dissociation with an ultraviolet laser, a facility with the standard capacity of 8.75 millions SWU per year is estimated to cost about 1 billion dollars. (Laser casts account for approximately half of the direct capital costs.) This is considerably lower than the estimated cost of a new gaseous diffusion plant (about 5 billion dollars) or that of a gas centrifuge plant (about 6 billion dollars). The annual operating cost for a laser isotope separation facility is estimated to be about 100 million dollars, in contrast to about 500 million for a gaseous diffusion plant and 100 to 200 million for a gas centrifuge plant. Our estimates of capital and operating costs for a laser isotope separation facility indicate a cost per SWU of about $30; the current commercial cost for enriched uranium is $110 per SWU.

The considerably lower cost per SWU for laser isotope separation opens the possibility of turning the large stockpile of wastes from gaseous diffusion plants into a valuable uranium resource. These wastes contain about a third of the $^{235}UF_6$ originally present in the feed material and are estimated to amount to more than 500,000 metric tons by the end of 1990—an amount containing enough uranium-235 for 1800 reactor-years of operation.

These advantages imply that laser isotope separation should be thoroughly investigated as a potentially economical process for large-scale production of enriched uranium. ■