APPENDIX VI-D

URANIUM LASER ISOTOPE SEPARATION

AND

NUCLEAR WEAPONS PROLIFERATION

(UNCLASSIFIED VERSION)

Prepared for the Office
of Technology Assessment

by the

United States Energy Research
and Development Administration

URANIUM LASER ISOTOPE SEPARATION AND NUCLEAR WEAPONS PROLIFERATION

This paper has been prepared in response to a request from the Office of Technology Assessment (OTA) for ERDA assistance in evaluating the proliferation implications of laser isotope separation (LIS). OTA will use this paper in the preparation of its assessment of Nuclear Proliferation and Safeguards which it is performing for the Senate Committee on Government Operations.

The OTA has requested that ERDA address the following specific topics:

1. A description of the technology.
2. Informed judgments on the proliferation implications of the technology five to 20 years hence
   a) with respect to the LDCs (Less Developed Countries)
   b) with respect to non-state organizations (i.e., terrorist or criminal).

   The case to be considered would be a laser isotope separation plant producing the order of magnitude of 100 kg of > 50% U-235 per year.

   c) an assessment of the feasibility of modifying an LIS process, which has been designed for low enrichment only, to yield high enrichments.
3. The possible indicators (personnel, equipment, etc.) in international or domestic trade that would provide an "early warning" of the construction of a clandestine LIS plant.

4. The possibility of detecting a clandestine LIS plant by physical surveillance (e.g., from satellite, aircraft, or other means).
5. An estimate of the efficacy of classification and export controls in delaying spread of the technology (i.e., how much time classification and export controls can buy).
6. An assessment of the problems and prospects of safeguarding an LIS facility.

1. Description of the Technology*

A. Introduction

The existence of differing atomic and molecular isotopic energy levels permits selective excitation of a given isotope by narrow band lasers. A generalized two-step process for Laser Isotope Separation (LIS) is illustrated in Figure 1. In the first step, the photons of a particular energy, hv_1 are absorbed by isotope "A" of an atomic or molecular mixture but not by isotope "B". The excited "A" atoms, or molecules, are then ionized or dissociated by photons of energy hv_2. The product of the reaction would then be separated to yield the enriched isotope.

The lasers required for isotope separation must have wavelengths which are narrow enough to take advantage of the isotope effect and must also have a sufficient power and repetition rate to react with a reasonable quantity of the desired isotope. These requirements are currently well beyond the present state-of-the-art.

Two LIS processes are currently under intensive development by ERDA; one is based on the excitation and dissociation of uranium hexafloride and the second based on the excitation and ionization of atomic uranium vapor.

B. Molecular Process

The molecular process being developed at the Los Alamos Scientific Laboratory. This method uses the isotonically selective

* A few classified sentences and phrases have been deleted from Section I.

laser irradiation and dissociation of gaseous UF_6 molecules. The action of the lasers causes one isotopic form (either ^{235}U or 238U) to break up, yielding UF_5 which rapidly condenses. Thus, the selective chemical action of the lasers is to preferentially convert a gas to a solid of the desired isotope. The solid UF_5 particles which are produced are then removed from the UF_6 process stream.

The molecular LIS process will not work at ordinary gas temperatures under ordinary gas flow conditions, but unique operating conditions have been devised for successful exploitation of this process. At ordinary temperatures the spectrum of UF_6 does not exhibit distinct isotopic characteristic features. Due to complex vibrational motions of the molecules, a single light frequency would excite both ^{235}U and ^{238}U. However, it has been demonstrated that if the UF_6 gas is cooled to very low temperatures (approximately 50 degrees K), these interferences are removed and distinct isotopic characteristics are obtained. To achieve the low temperature, UF_6 gas is mixed with a carrier gas and expanded through a nozzle to supersonic velocities. The nozzles are built with long slits for the expansion throat in order to facilitate passage of laser beams through the fast moving flow. Upon exiting the nozzle throat, either $^{235}U_6$ or $^{238}U_6$ can be selectively irradiated using appropriately chosen infrared lasers.

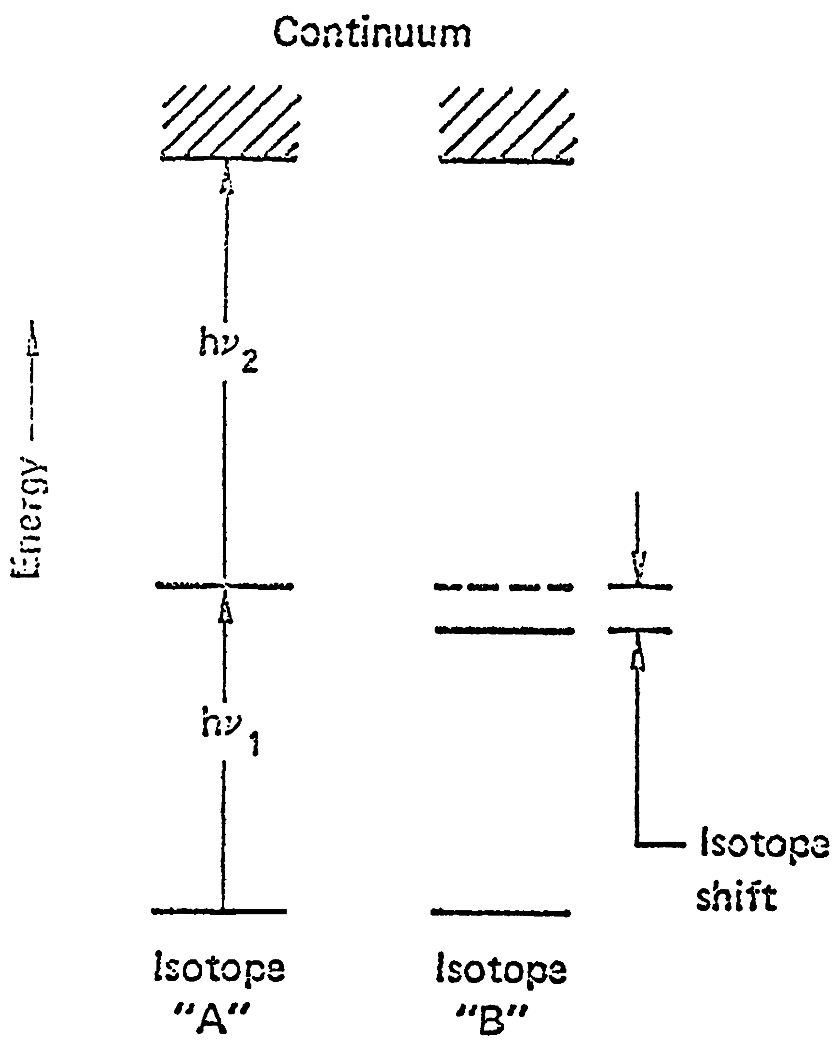
Once a particular isotope has been vibrationally excited by a tuned infrared laser, light from a selected ultraviolet laser then adds sufficient energy to cause dissociation into UF_5 + F. The UF_5 species mutually condense to form solid particles to be collected as the enriched product. At the present time the research effort is devoted to analyzing various process options, investigating possible scrambling effects which may interfere with efficient collection of the isotopic products, and developing the lasers required for the separation.

C. Atomic Vapor Process

Lawrence Liver-more Laboratory is developing an LIS process based on the isotopically selective photoexcitation of atomic uranium vapor. The atomic vapor process uses uranium metal as a feed material rather than UF_6. The atomic vapor process consists of three main sub-systems: (a) a source of uranium vapor, (b) a laser system capable of selectively exciting/ionizing the particular isotope desired, and (c) a technique for extracting the excited isotope from the isotonically mixed vapor and a collection system for handling the depleted tails and enriched product. Uranium vapor producing concepts considered to date are high temperature (equilibrium) sources of pure uranium and non-equilibrated sources of pure uranium vapor (electron beam bombardment).

Many lasers for the enrichment of atomic uranium vapor have been proposed. Because of the complex electronic structure of the uranium atom, and the distribution of the electrons among various energy levels at the working temperature, selective excitation and ionization can be **attained by a variety of** routes. The simplest one involves the use of two ultraviolet photons for the excitation and ionization steps. If an N-photon ("N" designating three **or more** photons) system is used, more lasers of differing frequencies may be required; however, such systems may be operated at wavelengths where dye lasers are more efficient. In variations of the N-photon scheme, the more efficient CO_2 infrared laser may be used to provide the final energy to ionize the excited uranium 235 atom.

FIGURE 1 GENERALIZED TWO-STEP PR CESS FOR ISOTOPE SEPARATION USING LASERS



1. Photons of energy $h\nu_1$ are absorbed by "A" but not by "B"
2. Excited "A" atoms (or molecules) are ionized (or dissociated) by photons of energy $h\nu_2$
3. Ions (or molecular fragments) are collected by physical or chemical processes

II. Proliferation Implications

This section examines the potential impact of LIS technology on the possible spread of nuclear weapons to additional countries. The various LIS efforts are only in an early state of development and will take some time to bring to production scale. Because it is difficult to judge the magnitude of threat from the standpoint of proliferation, statements concerning the possible impact of LIS are largely hypothetical. The effect of LIS technology on nuclear proliferation will depend to no small degree on the specific nature, cost, and the timing of the technology that ultimately emerges as the most feasible. In this connection, it should be noted that even though commercial feasibility is estimated to be at least 10 years away with additional time required to build a full-scale plant, use of LIS for small weapons programs could occur sooner.

11½ pages of classified material have been deleted here.

Although the development of LIS would increase the risk of proliferation, it would not in and of itself necessarily lead to the spread of nuclear weapons. The availability and cost of LIS technology are not the only considerations which may lead a country to acquire nuclear explosives or to select LIS as the preferred route to a nuclear explosives capability. A decision by a nonnuclear-weapon state to acquire a nuclear-weapons or other nuclear-explosives capability would depend on a number of complex political, diplomatic and military considerations. Many countries which already have the capability to develop nuclear weapons have decided for foreign policy or other reasons to foreswear the acquisition of nuclear weapons. In the final analysis, a country’s perception of its national security needs will probably be the most important factor in any decision to develop nuclear weapons. However, even in a case where the national security situation may warrant the acquisition of nuclear weapons, a combination of political constraints may tip the balance against acquiring them.

A lack of resources could also prevent a country which might otherwise wish to embark on a nuclear weapons program for doing so or, at least, greatly inhibit its efforts. Special nuclear material could be a key factor insofar as it would ordinarily be the limiting resource in the case of most non-nuclear countries which seek to acquire nuclear weapons. If such countries could not obtain nuclear weapons or special nuclear material directly from an external source, i.e., through theft or purchase, their basic options would be either to use fissionable material produced through their peaceful nuclear power or research programs or to initiate a new program to produce special nuclear material.

Most special nuclear material used in peaceful nuclear programs is presently subject to safeguards applied by the International Atomic Energy Agency and is also subject to some sort of peaceful uses guarantee by the consumer country. Non-nuclear weapon states party to the Treaty on the Non-Proliferation of Nuclear Weapons have undertaken to accept international safeguards on all their peaceful nuclear activities and have agreed not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices.

Any country considering diverting material for use in a nuclear weapons or nuclear explosives program would have to consider the significant political, legal and other costs associated with such an act. In the case of U.S.-supplied materials or equipment, such an act would be an abrogation of a legal agreement with the United States not to use U.S.-provided material or equipment for military purposes which we have construed as including development or use of any nuclear explosive device. Similar considerations would apply to the diversion of materials or equipment supplied by other nuclear exporting countries. Parties to the NPT would, moreover, be abrogating a commitment to all their treaty partners. The potential diverting country would have to assess the reactions of the United States and the international community, . particularly its immediate neighbors, who might feel threatened by such an action. Such an assessment would have to be made in a decision to divert material from any facility, whether LIS, gas centrifuge or a plutonium production or utilization facility that is subject to international safeguards and peaceful use guarantees.

No such abrogations have occurred to date. However, it is impossible to determine whether these considerations would outweigh a given country’s perceived need to acquire a nuclear explosives capability.

A country could-also decide to develop a nuclear explosive using unsafeguarded, undeclared or military facilities. One option would be the use of such facilities to produce plutonium. Although few non-nuclear countries have unsafeguarded plutonium available, many already have or could develop the capability to produce plutonium indigenously. Unclassified technology for constructing the needed facilities is readily available and generally well understood. Countries with advanced nuclear programs would be in an especially good position to carry out such a program. Given a supply of plutonium, many of these countries could then manufacture nuclear weapons of a crude implosion design. In fact, less plutonium would be required per weapon than in the case of enriched uranium.

The time required to build unsafeguarded reactors, fabrication plants, and reprocessing plants to generate plutonium, and eventually to manufacture a few rudimentary weapons, would take perhaps four to six or more years for the more advanced countries to 10 years or more for less-developed countries. If the means of delivery of such rudimentary weapons were of secondary importance, even a rather unsophisticated means of delivery might prove adequate. More advanced non-nuclear countries might, of course, wish to develop a modern nuclear strike force including a moderately sized stockpile, which would undoubtedly take more time than the four to six years required for rudimentary weapons.

If on the other hand, LIS technology were generally available, countries going nuclear may be more apt to select the uranium route since, other things being equal, it would present fewer problems than the plutonium route. In contrast to uranium, the radiotoxicity of plutonium would create a handling problem. In addition, the costs and technological requirements of constructing and operating a moderately advanced, small-scale (but militarily useful) centrifuge plant could be less than a large reactor-plutonium facility. These points would probably apply to LIS plants as well.

Moreover, natural uranium, the basic source for feed for LIS plants, is widely available, and a number of countries have significant, reasonably assured deposits of uranium ore. Even countries without deposits of uranium ore, however, could probably find a source willing to sell them the material. The other parts of the uranium cycle would present no insurmountable problems for many non-nuclear weapon countries.

In the final analysis, the question of whether a given country would decide to utilize LIS technology rather than some other means to acquire a nuclear explosives capability depends on a number of imponderable factors; the availability and economic cost of LIS technology vis-a-vis other technologies; the nature and urgency of its political and military objectives; its ability to acquire the necessary equipment and technology without any “strings attached”, and its willingness to abrogate solemn international commitments.

The Threat from Non-state, i.e., Subnational Organizations

The widespread development of LIS technology might also result in the increased availability of special nuclear material to terrorist or other subnational groups. This danger has two sources: (1) the possibility of using the technology directly to obtain special nuclear material, and (2) the likelihood of significant stockpiles of this material in many locations thus increasing opportunities for theft.

However, capabilities of non-state organizations in the near term are believed to be extremely low.

111. Foreign LIS Program Intelligence Indicators

a. Difficulty of Identification

It is difficult to positively identify a definite ongoing program or research in areas leading to such a program in most foreign countries. The several separation techniques and processes are in their infancy and in many cases, as stated, information for analysis of these processes is severely limited. Certainly, no large easily-identified complex such as with gaseous diffusion separation is necessary for a research program in LIS. Also research in areas which may touch upon one or two of the critical indicators of a laser isotope separation (LIS) program does not necessarily mean the existence of one. The research may apply to some other technology. Therefore, a matrix of critical intelligence indicators taken together is the only reasonable means of identification.

b. Intelligence Indicators

An attempt has ken made to establish what are the individual technology-related intelligence indicators. The following list of critical areas and indicators leans toward the LASL approach. As more research and information become available, additional items should be included. Not included is the obvious need to identify scientists and assess their potential.

In general, one would be interested in analyzing research, interest, or stated goals in photochemistry, high resolution spectroscopy, and high power tunable lasers. Other information would include **that** related to (1) semiconductor diode, gas, and/or dye lasers; (2) wavelengths (or frequencies), power levels, pulse repetition rates, or constituents of lasers; (3) concern with high purity feed material, or fluorine corrosion of equipment, especially compressors; and (4) research and lasing-related equipment compatible with specific infrared and ultraviolet wavelengths of ^{235}U, ^{238}U, UF_6, and carrier gases.

Intelligence Indicators for Laser Isotope Separation (LIS) Research

The ** indicates the most important indicators, a single * indicates next in importance, etc.

A. High Resolution, Laser Spectroscopy

1. Study of absorption spectrum of uranium, as well as other possible elements in combination with uranium.

** 2. Study of the exact frequencies of uranium isotope absorption lines. (7.7, 8.6, 12.1, 16μm in the ir and around 0.4μm in the uv)

3. Low power tunable lasers to operate over a narrow range around those wavelengths. (μ joule/pulse sufficient)

   a. Semiconductor diode lasers for spectroscopy tunable to the ir frequencies in question. (Atomic ratios specified)

   b. Dye laser for uv spectroscopy (LASL uses N_2 pumped dye laser of p-quaterphenyl)

   c. No particular requirement for pulsing.

B. <u>High Power Irradiation Laser Systems</u>

1. Infrared-range lasers

** a. Capable of high energy outputs

** b. High pulse rates

** c. Tunable over narrow ir range in question.

d. Gas Lasers

* (1) Physically large (e. g., TEA lasers for few mJ/pulse is 4 x 4 cm by 150 cm long)

(2) Use of TEA (Transverse Electric Atmospheric-pressure) laser for high energy output at high pulse rate.

(3) Use of gases which can lase at or near 7.7-16μm wavelengths. (e.g., CO, CO_2, OCS, CF_4, CS_2, C_2H_2, $CHBR_3$, C_2HD)

(4) Use of non-linear optical techniques to "downshift" frequencies of laser beams to regions of program interest.

2. Ultraviolet Range Lasers

** a. Capable of high energy outputs.

** b. High pulse rates

** c. Tunable over narrow range in the 0.2 to 0.4 μm wavelength region

d. Organic Dye Lasers

* (1) Physically large

* (2) Use of dyes with spectrum which brackets that of interest.

** (3) Solvents *in* which dyes dispersed must be optical (UV) grade and **used** in quantity.

(4) May have optical device for fine tuning.

(5) Work on high repetition rate dye laser systems.

C. Components -for Tuning Lasers

1. Superconducting air core magnets (perhaps 50-100 KGauss)
2. Crystals
3. Use of Raman Spin Flip (RSF) process to downshift emerging beams from crystals.
4. Optical gratings other frequency selective devices.

** 5. High reflectivity mirrors used to manage laser beams, made for wavelength of light to be reflected.

** 6. AM-reflective coatings, wavelength specific

D. Feed Material and Processing (The Atomic beam process would not be concerned with fluorine problems.)

* 1. Use of rapid cooling of UF_6 through spersonic expansion nozzle in order to collapse absorption spectrum.

* 2. Process for separating solid from gas. **(UF_6, $^{235}U F_6$)**

3. Concern with fluorine corrosion.
   a. Extensive use of nickel or Monel to avoid fluorine attack.
   c. Teflon-coated elastomeric O-rings. (Solid teflon tends to creep and other elastomers are chemically unstable)

** c. Contamination-free fluorine-compatible gas compressors.

E. Diagnostic Equipment

1. HF chemical lasers - tool for analyzing for traces of HF impurities in gas samples.
2. Modification of mass spectrometer for analysis of fluorine-related gaseous compounds.

3. Plasma diagnostics with lasers (e. g., cw He Ne, low power CO_2, high power pulsed CO_2 and ruby) done in single pulse mode, probably no fine tuning.

F. Electrical Equipment and Requirements

* 1. Energy storage and pulsing apparatus.

(1) Capacitors to store 10-100 times electrical energy as laser will deliver per pulse.

2. Switching Equipment. (large scale)

** 3. Electric Power into laboratory appropriate to serve a laser.

** 4. Electrical noise on telephone or power lines serving a laser lab, indicating pulse rates.

IV. DETECTION OF CLANDESTINE LIS PLANTS BY SURVEILLANCE

LIS technology would likely have small space and electrical power requirements. Hence, significant amounts of enriched uranium production could be carried out with little chance of detection. With the possible exception of some covert means, current detection systems would be of limited use. Thus the process would lend itself readily to the establishment of a clandestine facility.

Tracking feed material would not necessarily facilitate detection of a clandestine LIS facility. First, uranium ore production can be a by-product operation associated with other mineral mining activities, e.g., gold mining in South Africa, phosphate mining in Brazil, Israel and the US, and copper production in the US. In such a situation, not only would uranium mining become less costly, but the uranium mining operations could be more easily concealed. Second, uranium milling operations usually take place near the site of the mine so that, even though it may take 2000 metric tons of uranium ore to provide enough U-235 for a critical mass quantity (about 50 kgs bare sphere or about 20 kgs if reflected), the equivalent uranium ore concentrate actually shipped from the mill to the conversion plant would only be about 4 metric tons. The associated feed, metals processing and even the weapons fabrication facilities could be relatively small operations, which could easily be performed within the enrichment facility itself. To illustrate, a supply of ten metric tons of purified UF_6 or elemental U per month to a clandestine LIS plant could be delivered by one large truck, and could enable the plant to produce about 30 critical masses per year if complete separation of U-235 were achieved.

V. Efficacy of Classification and Export Controls in Delaying Spread of LIS Technology

A. Current U.S. Classification Policy

Section lly. of the Atomic Energy Act of 1954, as amended, define Restricted Data to include:

> "all data concerning (1) design, manufacture, or utilization of atomic weapons; (2) the production of special nuclear material; or (3) the use of special nuclear material in the production of energy"

except data which have been removed from the Restricted Data category or declassified upon determination pursuant to Section 142, that such data could be published without undue risk to the common defense and security.

In the area of isotope separation as with other atomic energy information, classification of information in the Restricted Data category is designed to prevent unauthorized disclosure of technology and equipment which would be detrimental to the common defense and security of the U.S.

Current ERDA policy provides that "research and development work on any method of isotope separation . . . would be unclassified as long as the Administrator is satisfied that the method does not have a reasonable potential for the separation of practical quantities of special nuclear materials." Methods judged as having such potential are classified as Restricted Data.

In the area of LIS, both processes described in this report (LASL and LLL) have been determined to fall into the category requiring classification under this policy. However, since the principles of LIS are not novel and many of the concepts involved in the development of LIS technology have been described in the open literature, it is not reasonable to attempt to classify everything about the U.S. LIS processes. Rather, our classification policy requires protection of process details such as unique design and engineering features and operating parameters, which appear critical to achieving a successful process.

Classification of Isotope Separation .Technology in the Private Sector

The definition of Restricted Data set forth in the Atomic Energy Act of 1954, as amended, encompasses information generated in the private sector as well as information developed by or on behalf of the U.S. Government.

Any privately generated information classified as Restricted Data under the Act must be protected in accordance with the various requirements of the Act and ERDA’s implementing regulations, including the requirements for physical security of facilities, the requirement for security clearances for all individuals having access to the information and the prohibition against communication of that data to any other nation.

In order to help assure that the U.S. Government is aware of all private work in areas which could come within the Restricted Data (RD) definition and therefore require classification, section 151c of the

Atomic Energy Act requires that any discovery useful in the production or utilization of SNM must **be** reported to ERDA or to the Commissioner of Patents:

> "c. Any person who has made or hereafter makes any invention or discovery useful in the production or utilization of special nuclear material or atomic energy, shall file with the Commission a report containing a complete description thereof unless such invention or discovery is described in an application for a patent filed with the Commissioner of Patents by such person within the time required for the filing of such report. The report covering any such invention or discovery shall be filed on or before the one hundred and eightieth day after such person first discovers or first has reason to believe that such invention or discovery is useful in such production or utilization.

In addition, regarding isotope separation work, ERDA has issued notices in the Federal Register providing information on what areas of development may come within the definition of RD and when ERDA should be informed of the status of such work, so that classified work is performed only under proper security controls and restrictions. The following is the **text** of the latest such Federal Register Notice dated August 1, 1972 regarding advanced methods of isotope separation, which includes work in the area of LIS.

Excerpt from <u>Federal Register</u>, Volume 37, No. 148 -- Tuesday, August 1, 1972, Page 15393

NOTICES

NOVEL METHODS OF ISOTOPE SEPARATION

Procedures for Reports on Research

The AEC has reviewed its declassification actions in the field of isotope separation to assure that they are consistent with the policy expressed in section 141 of the Atomic Energy Act, and to determine whether any further actions to assure the common defense and security or to permit and encourage the free interchange of ideas and criticisms are now appropriate in the light of the current state of the relevant technology. In this review the Commission has focused on the classification status of methods of isotope separation other than gaseous diffusion and gas centrifugation. In 1967, the Commission declassified all research and development work concerning any such other method of isotope separation until that method has a reasonable potential for the separation of practical quantities of special nuclear material. The public was notified of this action by a statement published in 32 F.R. 20888.

The Commission has reaffirmed that determination as best meeting current needs. It has also noted that as unclassified research and development on any such other method of isotope separation proceeds, there may come a stage at which the researcher will need classification advice in order to assure that classified work is performed only under proper security controls, and that correct and timely classification determinations are made, so that any restricted data involved would be protected in accordance with the Atomic Energy Act. Therefore, any person engaging in research and development on such other methods of isotope separation should notify the Commission when, in his opinion, the process has demonstrated, through experiments in the laboratory or through theoretical studies or calculations, that the process can separate uranium isotopes, so the Commission can give him appropriate classification and reporting guidance. Prompt guidance will be given. Reports should be submitted to Director, Division of Classification, U.S. Atomic Energy Commission, Washington, D.C. 20545.

Any researcher who believes his work may have proceeded to the point where it is no longer unclassified should proceed in accordance with 10 CFR Part 95, especially § 95.32.

Dated at Germantown, Md., this 25th day of July 1972.

W. B. McCool,
Secretary of the Commission.

[FR Doc.72-11917 Filed 7-31-72;8:46 am]

B. Efficacy of Classification

Classification of unique features or details of any new process, such as LIS, can make it more difficult for non-nuclear weapon states or non-state organizations to acquire enrichment process information which potentially may offer a relatively inexpensive means of acquiring SNM.

Our experience with older isotope separation processes should be noted here. Certain U.S. gaseous diffusion technology has remained classified for over 30 years and, while this has not prevented some other advanced industrial nations" from independently developing similar capabilities, classification has been a factor in preventing wide proliferation of this technology to many countries. Gas centrifuge is an example which applies even more directly to the LIS question. In this area, classification has been applied to significant features of U.S. work since 1960 and experience has indicated that this policy has been very effective in protecting unique U.S. developments. Again, classification by the U.S. cannot prevent other countries from developing indigenous capabilities through independent invention of the technologies. In the area of gas centrifuge, however, the U.S. was successful in arriving at an informal quadripartite agreement in 1960 with those Governments doing major development work, i.e., the UK, the FRG and the Netherlands, regarding classification of gas centrifuge technology. While other countries such as Italy, France and Japan continue to pursue some gas centrifuge work without an agreement to classify it, these countries do not have major programs and furthermore have not published their work.

Similarly, in the LIS area, classification of technology by the highly industrialized nations should serve to retard the progress of other countries in developing this method. However, it will be important to involve as many nations as possible in a common classification policy, starting with potential suppliers, and extending if possible to all nations with active LIS programs.

As a goal, an agreement should be reached with all nations working on any isotope separation methods to protect significant technology. Initial steps toward this goal are currently being pursued by ERDA in conjunction with the State Department.

It must be understood that national or even international classification provides only transitory protection for technology. It cannot guarantee that similar LIS processes may not be developed independently by other nations. Since LIS is a highly sophisticated technology, however, if classification is applied uniformly by all industrialized nations involved in development work, it could prove to be effective in delaying the spread of the technology. If other industrialized nations are not willing to classify their LIS developments, classification by the U.S. of our own work will still have some retarding effect on proliferation of the technology, but since many other countries are already working on LIS processes, the overall effectiveness of U.S. classification will depend on the significance of U.S. advances versus developments in other countries.

Export Controls

Special nuclear materials as well as Restricted Data can only be exported under a government-to-government agreement made pursuant to Section 123 of the Atomic Energy Act. Therefore, the U.S. has the mechanism for adequately reviewing proposed exports of classified items.

The U.S. Government also has extensive export controls over unclassified equipment, technology and materials in the uranium isotope separation area.

The principal restriction on the export of U.S. unclassified information and equipment is set forth in Section 57.b. of the Act*, which states it shall be unlawful for any U.S. citizen to directly or indirectly engage in the production of any special nuclear material outside of the United States except (1) under the Agreement for Cooperation, or (2) upon authorization by the ERDA after a determination that such activity will not be inimical to the U.S. interest.

The implementing ERDA regulation, 10 CFR 810, requires a specific authorization from the Administrator of ERDA for any U.S. person or company to engage in activities outside of the U.S. pertaining to designing, constructing, fabricating, furnishing, or operating facilities for the separation of isotopes of uranium or equipment or components specially designed for such facilities. The same requirement includes

*There are some items of equipment and materials useful in nuclear facilities that are controlled by the Department of Commerce. Some of these items can be exported under general authorizations; however, those items requiring a specific Commerce license are referred to the ERDA for recommendations=

the training of foreign personnel or furnishing of information not available to the public in published form.

Present export controls are comprehensive and should be adequate to control newly developing technologies or specially designed equipment. However, these export controls are effective only if significant items are identified and regulated through U.S. export control regulations. Since the LIS process is still at the R&D laboratory stage of development, it is not yet possible to identify all the significant items and know-how that should be controlled for national security reasons. As these items are identified, export licensing controls can be extended to cover them.

At present, the U.S. Government exercises export controls lasers and laser systems and specially designed components and parts of such systems, including amplification stages, and any equipment containing, or which is designed to contain, lasers. Controls are not applied, however, to low-power lasers and to certain specified civil equipment containing lasers, such as those commonly used in medical applications, educational devices, and clearly civil commercial applications.

Export controls cannot prevent another nation from independently developing a uranium isotope separation capability. At best, they could retard development and increase costs of the foreign process, if the U.S. has unilateral control over certain important technologies, equipment and material used in the process.

VI. Safeguards

The impact of LIS on the current system of international safeguards is potentially complex and far reaching. It should be recognized that the application of safeguards to existing enrichment plants is already a complicated problem.

The international safeguards[1/] which have been developed to ʻate by the IAEA appear to be reasonably complete and adequate for all phases of the nuclear fuel cycle from the chemical conversion stage onward except with respect to isotope separation plants. The reason international safeguards on such plants have not yet been fully developed stems from two factors. First, international safeguards tend to conflict with the requirement to protect the classified and proprietary information of such plants from dissemination to international inspectors. The IAEA, under U.S. and European pressure, seems to be arriving at a system of perimeter safeguards to achieve such protection, although many details relating to this system have yet to be worked out. Second, the need for such safeguards is only now arising, i.e., at the Almelo centrifuge facility in The Netherlands.

Apart from the possible calling into question of the basic validity of the current international safeguards system, the major implication for safeguards of LIS technologies is that, by making it much easier and

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1/ Comprised mainly of nuclear material accountability augmented by containment surveillance techniques. Physical security is applied by individual governments with guidance in the form of IAEA-sponsored recommendations.

cheaper to enrich uranium, they would increase the importance of material containing low concentrations of U-235 (i.e., source material and depleted uranium), by substantially reducing the cost of enrichment.

The potential of LIS to achieve high separation in a few steps is particularly noteworthy in this regard. Thus, these technologies would have the effect of increasing the significance of uranium mining, milling, refining, and conversion facilities, from the safeguards standpoint. Extension of IAEA inspections to cover these processes as well as locations containing quantities of depleted uranium from present enrichment plants, would tend to alleviate the problem, but the political and administrative feasibility of such extensions is questionable. In any case, as noted earlier, there are other sources of natural uranium which cannot be controlled.

Apart from the question of the increased significance of material containing low concentrations of U-235, there is the problem of devising national and international safeguards for prevention or deterrence of diversions of highly-enriched material from declared national LIS facilities. On the one hand, if the LIS techniques were widely utilized, the enrichment plants would be much more numerous; perhaps of such a nature that each constantly produced weapons-usable material which might be diverted during any brief lapse in inspection coverage. On the other hand, the necessary surveillance could be performed by IAEA inspectors or possibly by unattended instrumentation. Surveillance by IAEA inspectors might tax IAEA capabilities if many countries built such plants.

In addition to safeguards problems related directly to LIS plants, another problem stems from the possibility that such plants might lead to a large increase in the presence of highly-enriched uranium in other parts of the fuel cycle. This situation would increase possibilities for diversion and hence increase the required intensity of domestic physical security measures and international safeguards.

The most complicating feature of the LIS technologies with respect to safeguards is their potential for clandestine production of weapons-grade material. International safeguards as they now exist apply only to declared facilities and do not include procedures for seeking out clandestine facilities. Nor is it likely that international safeguards could feasibly be broadened to include such procedures.

Following receipt and review of this report, a series of questions requesting clarifications and addition to the report, focusing mainly on the classified portion, was submitted to ERDA. ERDA then prepared written answers to these questions. The ERDA response remain classified.

In addition, a classified meeting was held with ERDA, LLL, and LASL representatives to discuss all the material prepared by ERDA for OTA.