(i) Equipment for contacting chlorine and oxygen with the aqueous effluent from the isotope separation equipment and extracting the resultant U+4 into the stripped organic stream returning from the product end of the cascade; and

(ii) Equipment that separates water from hydrochloric acid so that the water and the concentrated hydrochloric acid may be reintroduced to the process at the proper locations.

B. In the solid-liquid ion-exchange process, enrichment is accomplished by uranium adsorption/desorption on a special, fast-acting, ion-exchange resin or adsorbent. A solution of uranium in hydrochloric acid and other chemical agents is passed through cylindrical enrichment columns containing packed beds of the adsorbent. For a continuous process, a reflux system is necessary to release the uranium from the adsorbent back in the liquid flow so that “product” and “tails” can be collected. This is accomplished with the use of suitable reduction/oxidation chemical agents that are fully regenerated in separate external circuits and that may be partially regenerated within the isotope separation columns themselves. The presence of hot concentrated hydrochloric acid solutions in the process requires that the equipment be made of or protected by special corrosion-resistant materials.

(1) Fast reacting ion exchange resins/adsorbents.

Especially designed or prepared for uranium enrichment using the ion exchange process, including porous macroporous resins, and/or particulate structures in which the active chemical exchange groups are limited to a coating on the surface of an inactive porous support structure, and other composite structures in any suitable form including particles or fibers. These ion exchange resins/adsorbents have diameters of 0.2 mm or less and must be chemically resistant to concentrated hydrochloric acid solutions as well as physically strong enough so as not to degrade in the exchange columns. The resins/adsorbents are especially designed to achieve very fast uranium isotope exchange kinetics (exchange rate half-time of less than 10 seconds) and are capable of operating at a temperature in the range of 100°C to 200°C.

(2) Ion exchange columns.

Cylindrical columns greater than 1000 mm in diameter for containing and supporting packed beds of ion exchange resin/adsorbent, especially designed or prepared for uranium enrichment using the ion exchange process. These columns are made of or protected by materials (such as titanium or fluorocarbon plastics) resistant to corrosion by concentrated hydrochloric acid solutions and are capable of operating at a temperature in the range of 100°C to 200°C and pressures above 0.7 MPa (102 psia).

(3) Ion exchange reflux systems.

(i) Especially designed or prepared chemical or electrochemical reduction systems for regeneration of the chemical reducing agent(s) used in ion exchange uranium enrichment cascades.

The ion exchange enrichment process may use, for example, trivalent titanium (Ti+3) as a reducing cation in which case the reduction system would regenerate Ti+3 by reducing Ti+4.

(ii) Especially designed or prepared chemical or electrochemical oxidation systems for regeneration of the chemical oxidizing agent(s) used in ion exchange uranium enrichment cascades.

The ion exchange enrichment process may use, for example, trivalent iron (Fe+3) as an oxidant in which case the oxidation system would regenerate Fe+3 by oxidizing Fe+2.

[61 FR 35604, July 8, 1996]

APPENDIX F TO PART 110—ILLUSTRATIVE LIST OF LASER-BASED ENRICHMENT PLANT EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

Note—Present systems for enrichment processes using lasers fall into two categories: the process medium is atomic uranium vapor and the process medium is the vapor of a uranium compound. Common nomenclature for these processes include: first category-atomic vapor laser isotope separation (AVLIS or SILVA); second category-molecular laser isotope separation (MLIS or MOLIS) and chemical reaction by isotope selective laser activation (CRISLA). The systems, equipment and components for laser enrichment plants include: (a) Devices to feed uranium-metal vapor for selective photo-ionization or devices to feed the vapor of a uranium compound for photo-dissociation or chemical activation; (b) devices to collect enriched and depleted uranium metal as “product” and “tails” in the first category, and devices to collect dissociated or reacted compounds as “product” and unaffected material as “tails” in the second category; (c) process laser systems to selectively excite the uranium-235 species; and (d) feed preparation and product conversion equipment. The complexity of the spectroscopy of uranium atoms and compounds may require incorporation of a number of available laser technologies.

All surfaces that come into contact with the uranium or UF₆ are wholly made of or protected by corrosion-resistant materials. For laser-based enrichment items, the materials resistant to corrosion by the vapor or liquid of uranium metal or uranium alloys include yttria-coated graphite and tantalum; and the materials resistant to corrosion by UF₆ include copper, stainless steel, aluminum, aluminum alloys, nickel or alloys.
Many of the following items come into direct contact with uranium metal vapor or liquid or with process gas consisting of UF₆ or a mixture of UF₆ and other gases:

1. **Uranium vaporization systems** (AVLIS). Especially designed or prepared uranium vaporization systems that contain high-power strip or scanning electron beam guns with a delivered power on the target of more than 2.5 kW/cm².

2. **Liquid uranium metal handling systems** (AVLIS).

   - Especially designed or prepared uranium metal handling systems for molten uranium or uranium alloys, consisting of crucibles and cooling equipment for the crucibles.
   - The crucibles and other system parts that come into contact with molten uranium or uranium alloys are made of or protected by materials of suitable corrosion and heat resistance, such as tantalum, yttria-coated graphite, graphite coated with other rare earth oxides or mixtures thereof.
   - Components for these assemblies are made of or protected by materials resistant to the heat and corrosion of uranium metal vapor or liquid, such as yttria-coated graphite or tantalum, and may include pipes, valves, fittings, "gutters", feed-throughs, heat exchangers and collector plates for magnetic, electrostatic or other separation methods.
   - These housings have multiplicity of ports for electrical and water feed-throughs, laser beam windows, vacuum pump connections and instrumentation diagnostics and monitoring with opening and closure provisions to allow refurbishment of internal components.
   - Supersonic expansion nozzles (MLIS).
   - Especially designed or prepared supersonic expansion nozzles for cooling mixtures of UF₆ and carrier gas to 150 K or less which are corrosion resistant to UF₆.
   - Uranium pentafluoride product collectors (MLIS).

   - Especially designed or prepared uranium pentafluoride (UF₅) solid product collectors consisting of filter, impact, or cyclone-type collectors, or combinations thereof, which are corrosion resistant to the UF₅/UF₆ environment.

3. **Separator module housings** (AVLIS).

   - Especially designed or prepared "product" and "tails" collector assemblies for uranium metal in liquid or solid form.

4. **Separator module housings** (AVLIS).

   - Especially designed or prepared cylindrical or rectangular vessels for containing the uranium metal vapor source, the electron beam gun, and the "product" and "tails" collectors.

5. **Supersonic expansion nozzles** (MLIS).

   - Especially designed or prepared supersonic expansion nozzles for cooling mixtures of UF₆ and carrier gas to 150 K or less which are corrosion resistant to UF₆.

6. **Uranium pentafluoride product collectors** (MLIS).

   - Especially designed or prepared uranium pentafluoride (UF₅) solid product collectors consisting of filter, impact, or cyclone-type collectors, or combinations thereof, which are corrosion resistant to the UF₅/UF₆ environment.

7. **UF₆/carrier gas compressors** (MLIS).

   - Especially designed or prepared compressors for UF₆/carrier gas mixtures, designed for long term operation in a UF₆ environment. Components of these compressors that come into contact with process gas are made of or protected by materials resistant to UF₆ corrosion.

8. **Rotary shaft seals** (MLIS).

   - Especially designed or prepared rotary shaft seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor with the driver motor to ensure a reliable seal against out-leakage of process gas or in-leakage of air or seal gas into the inner chamber of the compressor which is filled with a UF₆/carrier gas mixture.

9. **Fluorination systems** (MLIS).

   - Especially designed or prepared systems for fluorinating UF₅ (solid) to UF₆ (gas). These systems are designed to fluorinate the collected UF₅ powder to UF₆ for subsequent collection in product containers or for transfer as feed to MLIS units for additional enrichment. In one approach, the fluorination reaction may be accomplished within the isotope separation system to react and recover directly off the "product" collectors. In another approach, the UF₅ powder may be removed/transferred from the "product" collectors into a suitable reaction vessel (e.g., fluidized-bed reactor, screw reactor or flame tower) for fluorination. In both approaches equipment is used for storage and transfer of fluorine (or other suitable fluorinating agents) and for collection and transfer of UF₆.

10. **UF₆ mass spectrometers/ion sources** (MLIS).

    - Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking "on-line" samples of feed, "product" or "tails", from UF₆ gas streams and having all of the following characteristics:
      - Unit resolution for mass greater than 320;
      - Ion sources constructed of or lined with nichrome or monel or nickel plated;
      - Electron bombardment ionization sources; and
      - Collector system suitable for isotopic analysis.

11. **Feed systems/product and tails withdrawal systems** (MLIS).

    - Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to corrosion by UF₆, including:
      - Feed autoclaves, ovens, or systems used for passing UF₆ to the enrichment process;
      - Desublimers (or cold traps) used to remove UF₆ from the enrichment process for subsequent transfer upon heating;
      - Solidification or liquefaction stations used to remove UF₆ from the enrichment process by compressing and converting UF₆ to a liquid or solid; and

12. **Feed systems/product and tails withdrawal systems** (MLIS).
APPENDIX G TO PART 110—I LLUSTRATIVE
LIST OF PLASMA SEPARATION EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

Note—In the plasma separation process, a plasma of uranium ions passes through an electric field tuned to the 235U ion resonance frequency so that they preferentially absorb energy and increase the diameter of their corkscrew-like orbits. Ions with a large-diameter path are trapped to product enriched in 235U. The plasma, made by ionizing uranium vapor, is contained in a vacuum chamber with a high-strength magnetic field produced by a superconducting magnet. The main technological systems of the process include the uranium plasma generation system, the separator module with superconducting magnet, metal handling systems for molten uranium, and cryogenic refrigeration units capable of cooling equipment for the crucibles.

(1) Microwave power sources and antennae.
(2) Ion excitation coils.

APPENDIX H TO PART 110—I LLUSTRATIVE
LIST OF ELECTROMAGNETIC ENRICHMENT PLANT EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

Note—In the electromagnetic process, uranium metal ions produced by ionization of a salt feed material (typically UC14) are accelerated and passed through a magnetic field that has the effect of causing the ions of different isotopes to follow different paths. The major components of an electromagnetic isotope separator include: a magnetic field for ion-beam diversion/separation of the isotopes, an ion source with its acceleration system, and a collection system for the separated ions. Auxiliary systems for the process include the magnet power supply system, the