Especially designed or prepared heat exchangers, made of or protected by materials resistant to UF6 corrosion.

(6) Separation element housings. Especially designed or prepared separation element housings, made of or protected by materials resistant to UF6 corrosion, for containing vortex tubes or separation nozzles. These housings may be cylindrical vessels greater than 300 mm in diameter and greater than 900 mm in length, or may be rectangular vessels of comparable dimensions, and may be designed for horizontal or vertical installation.

(7) Feed systems/product and tails withdrawal systems. Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to UF6 corrosion, including:

(i) Feed autoclaves, ovens, or systems used for passing UF6 to the enrichment process;

(ii) Desublimers (or cold traps) used to remove UF6 from the enrichment process for subsequent transfer upon heating;

(iii) Solidification or liquefaction stations used to remove UF6 from the enrichment process by compressing and converting UF6 to a liquid or solid form; and

(iv) ‘Product’ or ‘tails’ stations used for transferring UF6 into containers.

(8) Header piping systems. Especially designed or prepared header piping systems, made of or protected by materials resistant to UF6 corrosion, for handling UF6 within the aerodynamic cascades. The piping network is normally of the “double” header design with each stage or group of stages connected to each of the headers.

(9) Vacuum systems and pumps. Especially designed or prepared vacuum systems having a suction capacity of 5 m³/min or more, consisting of vacuum manifolds, vacuum headers and vacuum pumps, and designed for service in UF6-bearing atmospheres. Especially designed or prepared vacuum pumps for service in UF6-bearing atmospheres and made of or protected by materials resistant to UF6 corrosion. These pumps may use fluorocarbon seals and special working fluids.

(10) Special shut-off and control valves. Especially designed or prepared manual or automated shut-off and control bellows valves made of or protected by materials resistant to UF6 corrosion with a diameter of 40 to 1500 mm for installation in main and auxiliary systems of aerodynamic enrichment plants.

(11) UF6 mass spectrometers/ion sources.

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:

(i) Unit resolution for mass greater than 320;

(ii) Ion sources constructed of or lined with nichrome or monel or nickel plated;

(iii) Electron bombardment ionization sources; and

(iv) Collector system suitable for isotopic analysis.

(12) UF6/carrier gas separation systems. Especially designed or prepared process systems for separating UF6 from carrier gas (hydrogen or helium). These systems are designed to reduce the UF6 content in the carrier gas to 1 ppm or less and may incorporate equipment such as:

(i) Cryogenic heat exchangers and cryoseparators capable of temperatures of −120 °C or less;

(ii) Cryogenic refrigeration units capable of temperatures of −120 °C or less;

(iii) Separation nozzle or vortex tube units for the separation of UF6 from carrier gas; or

(iv) UF6 cold traps capable of temperatures of −20 °C or less.

[61 FR 35603, July 8, 1996]

APPENDIX E TO PART 110—ILLUSTRATIVE LIST OF CHEMICAL EXCHANGE OR ION EXCHANGE ENRICHMENT PLANT EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

NOTE—The slight difference in mass between the isotopes of uranium causes small changes in chemical reaction equilibria that can be used as a basis for separation of the isotopes. Two processes have been successfully developed: liquid-liquid chemical exchange and solid-liquid ion exchange.

A. In the liquid-liquid chemical exchange process, immiscible liquid phases (aqueous and organic) are countercurrently contacted to give the cascading effect of thousands of separation stages. The aqueous phase consists of uranium chloride in hydrochloric acid solution; the organic phase consists of an extractant containing uranium chloride in an organic solvent. The contactors employed in the separation cascade can be liquid-liquid exchange columns (such as pulsed columns with sieve plates) or liquid centrifugal contactors. Chemical conversions (oxidation and reduction) are required at both ends of the separation cascade in order to provide for the reflux requirements at each end. A major design concern is to avoid contamination of the process streams with certain metal ions. Plastic, plastic-lined (including use of fluorocarbon polymers) and/or glass-lined columns and piping are therefore used.

(1) Liquid-liquid exchange columns.
pulsed columns with sieve plates, reciprocating plate columns, and columns with internal turbine mixers, especially designed or prepared for uranium enrichment using the chemical exchange process. For corrosion resistance to concentrated hydrochloric acid solutions, these columns and their internals are made of or protected by suitable plastic materials (such as fluorocarbon polymers) or glass. The stage residence time of the columns is designed to be short (30 seconds or less).

(2) Liquid-liquid centrifugal contactors.

Especially designed or prepared for uranium enrichment using the chemical exchange process. These contactors use rotation to achieve dispersion of the organic and aqueous streams and then centrifugal force to separate the phases. For corrosion resistance to concentrated hydrochloric acid solutions, the contactors are made of or are lined with suitable plastic materials (such as fluorocarbon polymers) or are lined with glass. The stage residence time of the centrifugal contactors is designed to be short (30 seconds or less).

(3) Uranium reduction systems and equipment.

(i) Especially designed or prepared electrochemical reduction cells to reduce uranium from one valence state to another for uranium enrichment using the chemical exchange process. The cell materials in contact with process solutions must be corrosion resistant to concentrated hydrochloric acid solutions.

The cell cathodic compartment must be designed to prevent re-oxidation of uranium to its higher valence state. To keep the uranium in the cathodic compartment, the cell may have an impervious diaphragm membrane constructed of special cation exchange material. The cathode consists of a suitable solid conductor such as graphite.

These systems consist of solvent extraction equipment for stripping the U⁴⁺ from the organic stream into an aqueous solution, evaporation and/or other equipment to accomplish solution pH adjustment and control, and pumps or other transfer devices for feeding to the electrochemical reduction cells. A major design concern is to avoid contamination of the aqueous stream with certain metal ions. For those parts in contact with the process stream, the system is constructed of equipment made of or protected by materials such as glass, fluorocarbon polymers, polyphenyl sulfate, polyether sulfone, and resin-impregnated graphite.

(ii) Equipment for contacting chlorine and oxygen with the aqueous effluent from the isotope separation equipment and extracting the resultant U⁴⁺ into the stripped organic stream returning from the product end of the cascade; and

(iii) 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 isotopic separation columns themselves. The presence of hot concentrated hydrochloric
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 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 containing 60% or more nickel and UF₆-resistant fully fluorinated hydrocarbon polymers.

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 liquid 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