

taking "on-line" samples of feed, product or tails, from UF₆ gas streams and having all of the following characteristics:

- (a) unit resolution for mass greater than 320;
- (b) ion sources constructed of or lined with nichrome or monel or nickel plated;
- (c) electron bombardment ionization sources;
- (d) having a collector system suitable for isotopic analysis.

[55 FR 30451, July 26, 1990]

APPENDIX D TO PART 110—ILLUSTRATIVE LIST OF AERODYNAMIC ENRICHMENT PLANT EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

NOTE—In aerodynamic enrichment processes, a mixture of gaseous UF₆ and light gas (hydrogen or helium) is compressed and then passed through separating elements wherein isotopic separation is accomplished by the generation of high centrifugal forces over a curved-wall geometry. Two processes of this type have been successfully developed: the separation nozzle process and the vortex tube process. For both processes the main components of a separation stage included cylindrical vessels housing the special separation elements (nozzles or vortex tubes), gas compressors and heat exchangers to remove the heat of compression. An aerodynamic plant requires a number of these stages, so that quantities can provide an important indication of end use. Because aerodynamic processes use UF₆, all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF₆. All surfaces which come into contact with the process gas are made of or protected by UF₆-resistant materials; including copper, stainless steel, aluminum, aluminum alloys, nickel or alloys containing 60% or more nickel and UF₆-resistant fully fluorinated hydrocarbon polymers.

The following items either come into direct contact with the UF₆ process gas or directly control the flow within the cascade:

- (1) Separation nozzles and assemblies. Especially designed or prepared nozzles that consist of slit-shaped, curved channels having a radius of curvature less than 1 mm (typically 0.1 to 0.05 mm). The nozzles are resistant to UF₆ corrosion and have a knife-edge within the nozzle that separates the gas flowing through the nozzle into two fractions.
- (2) Vortex tubes and assemblies. Especially designed or prepared vortex tubes that are cylindrical or tapered, made of or protected by materials resistant to UF₆ corrosion, have a diameter of between 0.5 cm and 4 cm, a length to diameter ratio of 20:1

or less and with one or more tangential inlets. The tubes may be equipped with nozzle-type appendages at either or both ends.

The feed gas enters the vortex tube tangentially at one end or through swirl vanes or at numerous tangential positions along the periphery of the tube.

- (3) Compressors and gas blowers.

Especially designed or prepared axial, centrifugal, or positive displacement compressors or gas blowers made of or protected by materials resistant to UF₆ corrosion and with a suction volume capacity of 2 m³/min or more of UF₆/carrier gas (hydrogen or helium) mixture. These compressors and gas blowers typically have a pressure ratio between 1.2:1 and 6:1.

- (4) Rotary shaft seals.

Especially designed or prepared seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor or the gas blower 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 or gas blower which is filled with a UF₆/carrier gas mixture.

- (5) Heat exchangers for gas cooling.

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 success-

fully 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.

Countercurrent liquid-liquid exchange columns having mechanical power input (*i.e.*, 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