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SPECIFICATION FOR HIGH DENSITY URANIUM DIOXIDE (NUCLEAR GRADE)

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SPECIFICATION FOR HIGH DENSITY URANIUM DIOXIDE (NUCLEAR GRADE)

1.0 This specification covers the physical and chemical requirements for high density, uranium dioxide (UO_2), nuclear grade, for use in packed particle nuclear fuel elements manufactured by vibrational compaction, or a similar process.

2.0 Sampling and Control Procedures

2.1 A representative sample of crushed material which passes through a 2 mesh sieve and not less than 1.5 weight percent shall be taken from each lot of material by riffling as it is crushed and screened.

2.1.1 A lot is defined as a batch of material which has been blended as an entity before packaging.

2.2 The representative sample taken in accordance with paragraph 2.1 shall be divided in two equal parts. One part of the divided sample shall be retained and handled by the Seller as specified under Sections 3.0 and 4.0, and the remaining part shall be forwarded to the Buyer.

2.2.1 Each sample shall be plainly marked as follows:

Purchase Order Number
Lot Number
Tare and Net Weight

2.3 The Seller's lot sample shall be thoroughly blended and divided in two approximately equal portions by riffling.

2.3.1 One portion shall be used for determination of chemical properties as specified under Section 3.0.

2.3.2 The remaining portion shall be used for determination of physical properties as specified under Section 4.0.

3.0 Chemical Properties

3.1 Analyses for chemical composition shall be made by the Seller from material representing each lot as selected under paragraph 2.3. The chemical composition thus determined shall conform to the requirements specified in Section 3.0.

3.2 The sample for chemical analyses shall be taken as specified under Section 2.0, and shall be crushed to pass through a 200 mesh Tyler standard sieve, or equivalent US sieve, and thoroughly blended.

3.3 The uranium dioxide shall conform to the following requirements as to chemical composition:

3.0 Chemical Properties (Continued)

3.3.1 The ratio of oxygen to uranium atoms shall be 2.00 ± 0.02 including analytical variance. The oxygen-to-uranium ratio shall be determined gravimetrically by oxidation at 900 C of the UO_2 to U_3O_8.

3.3.2 The uranium content shall be a minimum of 88.0 percent of the uranium dioxide.

3.3.3 The uranium isotopic composition or the enrichment shall be reported, or given to the Seller, and shall not be changed during Seller's processing. The U-235 content should be determined by mass spectrographic analysis.

3.4 Impurities

3.4.1 Impurities listed in Section 3.4 shall be reported on a uranium basis.

3.4.2 The total impurity content shall not exceed the "Equivalent Boron Content" (EBC) of 4 ppm on a weight basis. See the attached tabulation of EBC.

3.4.2.1 The EBC shall be calculated by the following formula:

$$EBC = \frac{(\text{Atomic weight boron}) \times (\sigma_a \text{ Impurity})}{(\sigma_a \text{ Boron}) \times (\text{Atomic weight Impurity})} \times (\text{ppm Impurity})$$

σ_a = 2200 meters per second thermal neutron absorption cross-section.

3.4.3 Elements which shall be also specifically reported are Ag, B, Cd, Cr, Co, Fe, Pb, Mn, Mo, Ni, Si, Sn, and Dy, Eu, Gd, Sm.

3.4.4 The carbon content shall not exceed 100 ppm as determined by a combustion method.

3.4.5 Nitrogen including nitrogen as uranium nitrides, shall not exceed 200 ppm. Nitrogen shall be determined by the Kjeldahl procedure using the following digestion technique. (Perform duplicate sample analyses.) Weight about 200 mg of sample -200 mesh UO_2 into a 50-ml beaker, and add 25-ml of 1 to 1 dilute hydrochloric acid, and then add 2-ml of H_2SiF_6. Heat just below boiling for 30 minutes. Add about 200 mg of copper selenate. Digest until solution is complete.

3.4.6 The chlorine content shall be 10 parts per millin (ppm) maximum.

3.4.7 The fluorine content shall be 10 ppm maximum.

3.4.8 Calcium and magnesium shall be 50 ppm maximum.

3.4.9 The moisture content shall be 100 ppm maximum. The moisture content should be determined by a solids moisture analyzer (coulometric-electrolytic method).

3.0 Chemical Properties (Continued)

3.4.10 The gas release comprising total gas exclusive of moisture, shall not exceed 0.05 cubic centimeters per gram of UO_2 at S.T.P. The material shall be crushed to -200 mesh and the gas released measured by vacuum out-gassing at 1×10^{-6} mm Hg. pressure for 30 minutes at 1000 C.

3.4.11 If recycle material is included in the lot, additional analyses may by required.

4.0 Physical Properties

4.1 The sample for physical properties shall be taken as specified under Section 2.0.

4.2 Detection within the entire sample under paragraph 4.1 of greater than 1% by weight of any combination of the following materials shall be cause for rejection, at the discretion of the Buyer, of any part or all of the lot represented by the sample.

4.2.1 Particles, crystals, and inclusions of any material other than UO_2.

4.2.2 Porous particles of UO_2. Porous particles are defined as particles containing interstices admitting absorption or passage of water.

4.3 The apparent density of the UO_2, as measured by the mercury-vacuum technique (i.e., Hg. pycnometer at S.T.P.) shall be greater than 10.80 grams per cubic centimeter.

4.3.1 The apparent density determination shall be performed in duplicate with 25 gram representative UO_2 samples of minus 6 plus 20 mesh fraction from the sample for physical properties as specified under paragraph 4.1.

5.0 Test Reports

5.1 The Seller shall prepare and deliver to the Buyer with the UO_2 three (3) copies of a written report which shall contain results of all physical and chemical tests performed on the material and the methods by which the above analyses were performed.

6.0 Packing and Marking

6.1 The uranium dioxide shall be packaged in vapor-tight bags. The sealed bag shall be inserted in a steel drum for shipping purposes.

6.1.1 Each drum of natural, or depleted UO_2, shall contain not more than 125 pounds.

6.2 The identity of all drums as to Lot Number shall be maintained. In addition, each drum shall be plainly marked as follows: Purchase Order Number, Can Number, Gross, Tare and Net Weight, and Name of Manufacturer.

7.0 Inspection

7.1 Inspection and testing shall be conducted in accordance with this specification by the Seller and at the Seller's expense. Material which, upon subsequent testing and inspection at the Buyer's plant, is found not to meet this specification is subject to rejection, and return to Seller at Seller's expense.

BORON EQUIVALENTS FOR IMPURITIES IN URANIUM

Impurity	σ_a (barns)[1]	Atomic Weight	KBC, parts per million
Aluminum	0.230	26.98	0.000122
Barium	1.170	137.34	0.000122
Beryllium	0.010	9.01	0.000015
Boron	755	10.81	0.999999
Calcium	0.43	40.08	0.000153
Cadmium	2550	112.40	0.325097
Carbon	0.00373	12.01	0.000004
Chromium	2.90	52.00	0.000799
Cobalt	38.00	58.93	0.009239
Copper	3.85	63.54	0.000868
Iron	2.62	55.85	0.000672
Lead	0.170	207.19	0.000011
Magnesium	0.069	24.32	0.000040
Manganese	13.20	54.93	0.003443
Molybdenum	2.70	95.94	0.000403
Nickel	4.60	58.71	0.001122
Nitrogen	1.88	14.00	0.001924
Oxygen	0.0002	16.00	--
Phosphorous	0.19	30.97	0.000087
Silicon	0.13	28.09	0.000066
Silver	62.0	107.87	0.008236
Tin	0.60	118.70	0.000072
Tungsten	19.20	183.85	0.001496
Vanadium	5.00	50.94	0.001406
Zinc	1.10	65.37	0.000241
Zirconium	0.185	91.22	0.000029
Samarium	5500	150.35	0.524575
Europium	4600	152.00	0.433973
Gadolinium	46000	157.26	4.194580
Dysprosium	1100	162.51	0.097064

(1) Brookhaven National Laboratory Publication BNL-325, Second Edition, July 1958, and Supplement #1, January, 1960.

NOTE: The above listed elements are to be included in the calculation of the KBC, but are not necessarily all the elements to be considered as the total impurity content. The Seller shall make and report impurity analyses of uranium dioxide for the elements specifically listed in the specifications.